Travel Model Development: Comparison to Legacy Model

Technical Paper

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1 Introduction

MTC recently completed the development of a new activity-based travel model (*Travel Model One*) to supersede its legacy trip-based model (*BAYCAST*). The methods behind these two systems are very different. *Travel Model One* is based on a simulation of the choices of individual households and the persons who comprise these households. It takes advantage of powerful computers and implements the microeconomic theory of individual travel demand. *BAYCAST* adheres to simpler methods, which describe aggregate relationships between travel-related variables and outcomes. General descriptions of trip- and activity-based travel models as well as the advantages of activity-based approaches can be found in the *NCHRP Synthesis 406: Advanced Practices in Travel Forecasting*[1].

Because *Travel Model One* relies on relatively new methods, it is reasonable to expect some reticence among stakeholders to rely upon its forecasts. Therefore, it is desirable to demonstrate that the advanced functionality of *Travel Model One* does not come at the expense of inconsistency with the outcomes stakeholders are familiar and comfortable with. That demonstration is the purpose of this paper.

The consistency between the models is demonstrated by comparing tabulations of the results when the models are applied to inputs representing transportation networks and uses of land present during the year 2000. The aggregate results of the two models are compared with each other, and also with observed data (where available). The models may contain different sensitivities to changes in input variables. However, if they produce similar results for the base year, the overall level of demand to which the sensitivities are applied would be similar, and consistent (if diverging) forecasts should result.

1.1 A Note on Method

Travel Model One is an activity-based model in which the primary unit of analysis is a tour (activities occur between tours); *BAYCAST* is a trip-based model in which the primary unit of analysis is a trip. A tour is a sequence of trips from a primary origin, such as a residence, to a series of stops, including a primary destination, such as a place of work, and back to the primary origin. Tours, therefore, are a collection of trips. In order to compare the outcomes forecasted by *BAYCAST* to the outcomes forecasted by *Travel Model One*, the results from *Travel Model One* must be dramatically simplified – information about tours must be removed to reveal trip-based behavior. Said another way, comparisons between activity-based and trip-based models must necessarily be done on the terms of the trip-based model.

This document compares the results of *Travel Model One*[2] to those of *BAYCAST* presented in the May 2004 report *2000 Base Year Validation of Travel Demand Models for the San Francisco Bay Area (BAYCAST-90)*.[3]

Because the units of analysis are different between the two models and because some of the raw model outputs, tabulation scripts, and sources of observed data used in the creation of the trip-

[1] Available here: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_406.pdf.

[2] Specifically version 0.1.

[3] Available here: http://mtc.ca.gov/maps_and_data/datamart/forecast/.

based model validation are not available, not easily accessible, or not described with sufficient detail for replication, the tabulations required to fit the activity-based model results into the format of the 2004 trip-based model report had to be inferred in some cases. Therefore, it is expected that some of the comparisons will be inconsistent. Reasonable effort was made to identify and rectify sources of inconsistency between the tabulations, but not all deviations in methods could be corrected. Evaluation of the consistency between the two models should therefore be based on the preponderance of the evidence and not on any one comparison.

Travel Model One produces a host of other outputs that do not fit into the trip-based paradigm which have been examined against observed data; please see the April 2011 report *DRAFT Travel Model Development: Calibration and Validation* for details[4].

1.2 A Note on Philosophy

Development of a comprehensive travel model proceeds in a series of phases: design, estimation, implementation, calibration, validation, and application testing. The final development phases of calibration, validation, and application testing usually proceed iteratively. During this process, estimated parameters are adjusted or "calibrated" to correct for differences between the measurement of variables in estimation data sets and the implemented model data, the aggregate model outputs are compared to or "validated" against observed data, iteratively, until the developers are content with the performance of both the calibration and validation. Application testing then informs the developers as to the reasonableness of the model's aggregate response to its inputs – these results may motivate additional calibration and validation.

A variety of opinions exist among transportation planning professionals regarding the approach one should take in model calibration. One philosophy holds the match between the model outputs and the observed model validation targets paramount. This approach often leads to the inclusion of a large number of parameters not found in model estimation. The developers of the legacy *BAYCAST* model subscribed to this approach. For example, the *BAYCAST* trip distribution models contain a large number of "k-factors" used to match the observed number of trips going between each origin/destination super-district[5] pair. The home-based work mode choice model contains geographic-specific constants for each alternative used to match the distribution of travel modes within each super-district and the transit vehicle boardings for each large operator in the region.

The advantage of this calibration approach is that short-term forecasts for small changes in model inputs are very accurate because each significant travel market is perfectly sized (i.e. fit to match observed behavior). The disadvantage of this approach is a generally inaccurate representation of responses to large projects, long-term shifts, and/or structural changes in the system. The proliferation of parameters in the model calibration restricts the sensitivity of the forecast to inputs that deviate any more than a small amount from their values in the base year.

Another philosophy of model calibration seeks a balance between parsimonious parameters and the match between tabulations of modeled and observed data. The development of *Travel Model One* followed this approach. Adjustments to constants in discrete choice models were made to

[4] The document is available for download here: http://mtcgis.mtc.ca.gov/foswiki/Main/Development.

[5] A "super-district" is a convenient unit of geography used to summarize model results; an interactive map of MTC's super-districts is available here: http://geocommons.com/maps/58539.

match the observed shares for each alternative, but constants were not segmented for new variables or beyond the degree to which differences were found significant in model estimation. New variables were occasionally introduced to better match target tabulations, but done so carefully with an eye towards avoiding potentially perverse behavioral responses.

The advantage of this approach is that the sensitivity to changes in land use, transportation infrastructure, and transport policy variables is maintained. The disadvantage of this approach is that not all markets are perfectly sized, and some deviations from the observed tabulations will exist when the data are sliced into multiple simultaneous dimensions.

Because of the differences in philosophy, and because any "observed" data reported here were taken from the trip-based model targets, it is expected that the trip-based model will more closely match any observed values contained herein. Greater deviations between the observed and modeled values for any particular tabulation should not be interpreted as a deficiency of the activity-based model unless the differences are systematic and not explainable or counter-balanced by other differences. Indeed, given that the activity-based model relies on explanatory variables rather than constants to produce the majority of the system's characteristic patterns, any tabulation where differences can be considered small represents a triumph of the model. The value of the activity-based model's emphasis on the behavior of the individual traveler is that a reasonable degree of match between observed and modeled travel patterns can be obtained without a stifling excess of free parameters.

* * * * *

The following sections present comparisons of tabulations between the activity-based and trip-based (or "four-step") models in the order with which they are generated in the trip-based model: household demographics and automobile ownership, trip generation, trip distribution, mode choice, time of day, and trip assignment. Tabulations for the activity-based-model appear under the heading "ABM" and tabulations for the trip-based model appear under the heading "4-step."

2 Household Demographics and Automobile Ownership

This section presents the results for the number of workers and vehicles owned in households sub-models.

The trip-based model uses a nested logit formulation, taking the number of households of each income quartile in each zone and applying the logit shares to obtain the number of households in each of nine worker/automobile ownership categories. The model contains an alternative-specific constant unique for each income quartile and super-district of residence.

The activity-based model creates a synthetic population by sampling (with replacement) households from the Census Public Use Microdata Sample (PUMS). The probability of selection within each travel analysis zone (TAZ) is adjusted using iterative proportional fitting to simultaneously match the marginal distributions of several control totals of interest, including the income and number of workers in the household. Individual households in the synthetic population then choose a household automobile ownership level via a multinomial logit model.

Table 1 presents the number of households by income quartile (note that these income breakpoints are used throughout the document) and number of workers. The match between the percentage of each level of household employment within each income quartile is very close between the two models and the Census. The overall number of households is greater by roughly 130,000 in the activity-based model because the synthetic population includes group quarters residents, which are excluded from the four-step tabulations. These group quarter residents tend to have lower income and automobile ownership levels than non-group quarters residents, which explains differences in the relevant income/automobile ownership cells.

Table 1: Zero-, One-, and Multi-Worker Households by Household Income (1989 dollars)

Household Income (1989 $)	Source	Zero workers	% Zero workers	One worker	% One worker	Multiple workers	% Multiple workers	Total
Low	Census	313,589	(49.1%)	252,222	(39.5%)	73,046	(11.4%)	638,858
(<25.0K)	4-step	336,787	(51.9%)	233,472	(36.0%)	78,287	(12.1%)	648,546
	ABM	410,196	(54.2%)	268,141	(35.5%)	77,484	(10.3%)	755,821
Med.-Low	Census	108,839	(18.8%)	280,185	(48.3%)	190,810	(32.9%)	579,835
(25.0-45.0K)	4-step	86,498	(16.4%)	252,119	(47.8%)	188,739	(35.8%)	527,356
	ABM	97,850	(25.2%)	252,878	(48.1%)	174,242	(33.2%)	524,970
Med.-High	Census	48,702	(8.0%)	217,382	(35.7%)	342,024	(56.2%)	608,108
(45.0-75.0K)	4-step	58,456	(9.3%)	234,243	(37.4%)	333,305	(53.2%)	626,004
	ABM	59,865	(9.5%)	221,834	(35.2%)	347,992	(55.3%)	629,691
High	Census	51,867	(8.1%)	168,455	(26.4%)	418,855	(65.5%)	639,177
(>75.0K)	4-step	38,975	(5.9%)	195,473	(29.4%)	429,661	(64.7%)	664,109
	ABM	39,400	(5.7%)	177,169	(25.8%)	469,933	(68.5%)	686,502
Total	Census	522,997	(21.2%)	918,244	(37.2%)	1,024,735	(41.6%)	2,465,977
	4-step	520,716	(21.1%)	915,307	(37.1%)	1,029,992	(41.8%)	2,466,015
	ABM	607,311	(23.4%)	920,002	(35.4%)	1,069,651	(41.2%)	2,596,984

Table 2 presents the number of households by income quartile and automobile ownership category. The trip-based model contains alternative-specific constants for each cell. In the activity-based model, income is considered via a three-parameter, piecewise linear function operating on a continuous income variable. The close match between estimated and observed data obviated additional calibration based on income.

Table 2: Household Automobile Ownership by Income (1989 dollars)

Household Income (1989 $)	Source	AO = 0	% AO = 0	AO = 1	% AO = 1	AO = 2+	% AO = 2+	Total
Low	Census	162,307	(25.4%)	316,002	(49.5%)	160,548	(25.1%)	638,858
(<25.0K)	4-step	167,761	(25.9%)	342,234	(52.8%)	138,551	(21.4%)	648,546
	ABM	168,250	(22.3%)	386,809	(51.2%)	200,762	(26.6%)	755,821
Med.-Low	Census	46,424	(8.0%)	242,125	(41.8%)	291,285	(50.2%)	579,835
(25.0-45.0K)	4-step	44,132	(8.4%)	216,190	(41.0%)	267,034	(50.6%)	527,356
	ABM	40,696	(7.8%)	201,621	(38.4%)	282,653	(53.8%)	524,970
Med.-High	Census	22,195	(3.6%)	157,764	(25.9%)	428,149	(70.4%)	608,108
(45.0-75.0K)	4-step	23,884	(3.8%)	156,845	(25.1%)	445,275	(71.1%)	626,004
	ABM	28,809	(4.6%)	156,953	(24.9%)	443,929	(70.5%)	629,691
High	Census	15,487	(2.4%)	99,771	(15.6%)	523,919	(82.0%)	639,177
(>75.0K)	4-step	11,455	(1.7%)	100,969	(15.2%)	551,685	(83.1%)	664,109
	ABM	21,418	(3.1%)	101,181	(14.7%)	563,903	(82.1%)	686,502
Total	Census	246,413	(10.0%)	815,662	(33.1%)	1,403,901	(56.9%)	2,465,976
	4-step	247,232	(10.0%)	816,238	(33.1%)	1,402,545	(56.9%)	2,466,015
	ABM	259,173	(10.0%)	846,564	(32.6%)	1,491,214	(57.4%)	2,596,984

Table 2 presents the joint distribution of workers and automobile ownership category in the household for each county in the region. The trip-based model includes geographic constants specific to each of the 34 super-districts. The activity-based model contains two county-based geographic constants to address the outliers of urban San Francisco versus rural Solano, Napa, and Sonoma counties. Since the explanatory variables in the activity-based automobile ownership model (such as travel time savings to work, which is only measurable in a micro-simulation context) explain the majority of geographic differences in behavior, further calibration was unnecessary.

Table 3: Zero-, One-, and Multi-worker Households by Automobile Ownership and County of Residence

County *	Zero Workers, Zero Autos			Zero Workers, One Auto			Zero Workers, Multiple Autos			Zero Workers		
	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM
SF	41,276	40,207	37,622	30,798	29,733	43,980	8,955	8,720	7,942	81,029	78,660	89,544
SM	8,992	9,292	8,306	24,627	24,972	29,487	19,065	18,696	17,160	52,684	52,960	54,953
SC	16,744	16,714	23,065	42,702	42,503	61,877	38,304	38,142	38,685	97,750	97,359	123,627
AL	30,135	30,486	30,848	52,057	51,919	64,099	33,060	32,880	35,514	115,252	115,285	130,431
CC	13,126	13,282	9,770	34,175	34,249	44,162	27,435	27,316	27,076	74,736	74,847	81,008
SOL	4,728	4,737	7,174	12,093	12,087	20,099	10,356	10,336	10,646	27,177	27,160	37,919
NAP	1,762	1,752	2,369	6,118	6,073	7,277	3,744	3,721	3,720	11,624	11,546	13,366
SON	6,349	6,379	7,583	20,815	20,879	23,074	13,893	13,911	14,171	41,057	41,169	44,828
MAR	2,647	2,708	4,864	11,088	11,115	19,240	7,953	7,907	7,501	21,688	21,730	31,605
Total	125,759	125,557	131,601	234,473	233,530	313,295	162,765	161,629	162,415	522,997	520,716	607,311

* SF – San Francisco; SM – San Mateo; SC – Santa Clara; AL – Alameda; CC – Contra Costa; SOL – Solano; NAP – Napa; SON – Sonoma; MAR – Marin.

County	One Worker, Zero Autos			One Worker, One Auto			One Worker, Multiple Autos			One Worker		
	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM
SF	35,006	34,564	43,513	70,446	69,375	63,655	24,769	24,409	23,840	130,221	128,348	131,008
SM	4,167	4,294	4,705	42,295	42,935	42,658	42,717	42,105	45,226	89,149	89,334	92,589
SC	9,293	9,275	11,489	95,337	94,942	82,911	106,387	105,932	99,764	211,017	210,149	194,164
AL	19,306	19,467	22,202	97,115	96,913	86,416	81,172	80,844	92,604	197,593	197,224	201,222
CC	6,589	6,655	4,478	55,654	55,796	55,949	67,435	67,228	69,438	129,593	129,679	129,865
SOL	2,502	2,505	1,976	19,181	19,165	19,456	24,248	24,231	26,162	45,931	45,901	47,594
NAP	569	562	583	6,708	6,661	7,341	8,527	8,469	10,017	15,804	15,692	17,941
SON	2,039	2,039	2,441	27,141	27,201	27,867	29,704	29,716	35,326	58,884	58,956	65,634
MAR	1,363	1,400	1,365	19,073	19,174	18,579	19,501	19,450	20,061	39,937	40,024	40,005
Total	80,834	80,761	92,752	432,950	432,162	404,832	404,460	402,384	422,438	918,244	915,307	920,002

County	Multiple Workers, Zero Autos			Multiple Workers, One Auto			Multiple Workers, Multiple Autos			Multiple Workers		
	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM
SF	15,520	16,254	21,652	39,736	40,924	38,351	64,319	65,511	68,022	119,575	122,689	128,025
SM	2,448	2,534	1,564	13,362	13,802	13,006	95,549	95,474	101,449	111,359	111,810	116,019
SC	6,831	6,854	3,290	27,224	27,236	25,500	224,413	224,264	247,897	258,468	258,354	276,687
AL	8,061	8,199	6,018	32,815	33,189	24,037	169,044	169,468	187,430	209,920	210,856	217,485
CC	2,991	3,052	1,022	14,414	14,570	12,856	121,739	121,981	129,256	139,144	139,603	143,134
SOL	1,190	1,192	430	5,970	5,977	4,531	50,141	50,173	52,101	57,301	57,342	57,062
NAP	399	393	135	2,279	2,279	1,643	15,574	15,492	16,370	18,252	18,164	18,148
SON	1,440	1,460	510	7,009	7,060	5,348	63,568	63,758	66,938	72,017	72,278	72,796
MAR	940	976	199	5,430	5,509	3,165	32,329	32,411	36,931	38,699	38,896	40,295
Total	39,820	40,914	34,820	148,239	150,546	128,437	836,676	838,532	906,394	1,024,735	1,029,992	1,069,651

3 Trip Generation

This section presents the results for the number of trips by purpose originating in each geographic area.

As noted previously, the primary unit of analysis in the trip-based model is the trip. These trips are segmented into several purposes. Trips with an origin or destination at home are home-based. Each trip to or from home is called a production; the non-home location at the other end of a home-based trip is called an attraction. Trips with no home end are non-home-based, where the origin end of the trip is the production and the destination end of the trip is the attraction. The trip-based model generates trips by applying rates to the number of households in each zone to obtain the number of productions, and applying rates to the number of jobs of different types to obtain the number of attractions.

The primary unit of analysis in the activity-based model is the tour, which is a sequence of trips from a primary tour origin, to a series of stops including a primary tour destination, and back again. The model defines all tours as home-based with the exception of "at-work" sub-tours, which are tours that originate and return to work (e.g., having lunch at a nearby restaurant). Using a series of logit models, household, person, and network (i.e. accessibility to employment) characteristics determine each simulated person's number of tours by purpose. After determining the primary anchor destination, departure and arrival time at the primary tour origin, and primary travel mode of each tour, the frequency, purpose, and locations of intermediate stops on each tour are chosen. This combination of tour frequency, destination choice, stop frequency, stop purpose, and stop location choice determine the number trips by purpose, as categorized in the trip-based model paradigm.

In both the trip-based and activity-based models, commercial truck trips are generated using a trip-based formulation. The rates are based on the employment by category in each zone.

The number of trip productions and attractions are shown for each non-commercial purpose, super-district, and county (and income quartile for work) in Table 4 through Table 7. The general consistency of the results across the geographic areas validates multiple parts of the activity-based model. Tour frequency must be correct to produce a consistent number of home-based trip productions in each area. The "size terms" in the tour destination and stop location choice model – linear combinations of employment by type which determine the demand for activities at a particular zone – must be correct to produce a consistent number of trip attractions. Also, stop frequency must be correct to produce a similar relative prevalence of home-based and non-home-based travel.

Some differences between the trip-based and tour-based models are evident. First, the total number of home-based work trips is lower in the tour-based model. It is possible this difference indicates that the number of intermediate stops on work tours is too high. However, some trip-based model developers eliminate very short legs from travel on the way to work when developing calibration targets. Labeling such travel home-based work results in greater model fidelity because trip-based models generally have a more sophisticated representation of home-based travel than non-home-based travel. It is also possible that the trip-based model was calibrated to the Census journey to work data, which tabulates workplaces, rather than trips. If so, the trip-based model would include extra trips because not all workers travel to work during

the typical weekday represented by both travel models. In either case, the correlation between home-based-work trip rates over the super-districts in the two models is greater than 0.99.

The lower number of home-based work trips is counter-balanced by a greater number of home-based other and non-home-based trips, as shown in Table 6. This difference is consistent with either of the above hypotheses regarding stop frequency, as these would be the trips created by a non-work stop on a work-based tour. However, the excess of 3,300,000 other trips more than covers the 900,000 deficit in home-based work trips – thus the activity-based model generates more total trips than the trip-based model. One possible source of the difference is the adjustment of tour frequency targets from the observed data in the household survey. It is well-known that respondents to household travel surveys tend to underreport non-work tours and trips. Therefore, during calibration of the activity-based model, the target number of non-work tours was increased by 13 percent from the value tabulated using the household survey. Even if these tours had no intermediate stops, this increase would account for at least one million additional trips. The frequency of at-work sub-tours was similarly increased.

Because of the known biases in the household survey, if the developers of the trip-based model did not factor up non-work trip rates from their observed values, the trip-based model would underestimate the prevalence of non-commercial travel. If that were the case, additional trips would have to come from commercial vehicles. The trip-based model contains 274,000 heavy truck trips and 3,100,000 small truck trips. The same commercial vehicle model was borrowed for the activity-based model, but the very small truck trip rates were decreased by 40 percent, based on highway assignment results and comparisons with truck trips rates from other regional models.

Table 4: Home-Based Work Trip Productions by Household Income and Super-district of Residence

Super-district	HBW Productions (Residence End)										
	Income Q1		Income Q2		Income Q3		Income Q4		Total		Percent
	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	Difference
Greater Downtown San Francisco	25,379	22,022	21,845	26,631	22,165	21,019	31,372	25,227	100,761	94,899	-6%
San Francisco Richmond District	23,140	15,829	37,069	36,983	52,338	48,398	87,834	80,750	200,381	181,960	-9%
San Francisco Mission District	28,770	21,178	52,440	49,343	79,106	70,801	92,312	85,674	252,628	226,996	-10%
San Francisco Sunset District	9,003	8,183	19,595	18,425	33,327	29,079	44,988	38,732	106,913	94,419	-12%
Daly City and San Bruno	19,704	14,249	45,325	38,562	82,198	69,571	83,103	72,755	230,330	195,137	-15%
San Mateo and Burlingame	11,889	9,100	26,854	23,423	47,093	38,304	94,610	68,694	180,446	139,521	-23%
Redwood City and Menlo Park	15,030	11,563	27,921	24,153	44,673	35,350	96,681	71,473	184,305	142,539	-23%
Palo Alto and Los Altos	10,815	7,943	18,000	16,693	28,498	25,777	87,099	65,852	144,412	116,265	-19%
Sunnyvale and Mountain View	16,302	9,965	31,459	29,520	61,854	52,557	85,416	76,786	195,031	168,828	-13%
Cupertino and Saratoga	17,891	10,423	35,096	31,385	64,545	51,539	137,033	112,030	254,565	205,377	-19%
Central San Jose	30,758	24,616	47,416	45,172	66,629	56,286	66,917	60,916	211,720	186,990	-12%
Milpitas and East San Jose	20,117	13,514	43,241	36,397	88,224	72,048	121,443	114,801	273,025	236,760	-13%
South San Jose	11,178	5,942	24,339	19,800	54,730	43,699	85,838	76,707	176,085	146,148	-17%
Gilroy and Morgan Hill	6,932	4,480	11,961	9,180	21,544	16,999	30,080	24,110	70,517	54,769	-22%
Livermore and Pleasanton	8,668	4,272	19,744	15,301	44,562	35,634	64,852	55,260	137,826	110,467	-20%
Fremont and Union City	16,417	10,480	38,806	30,372	83,657	67,420	105,788	89,688	244,668	197,960	-19%
Hayward and San Leandro	33,108	24,692	64,419	55,496	91,647	73,473	67,045	59,137	256,219	212,798	-17%
Oakland and Alameda	60,708	48,398	74,928	69,708	82,515	69,103	85,565	73,452	303,716	260,661	-14%
Berkeley and Albany	26,283	22,087	27,365	25,290	33,390	27,717	40,789	35,761	127,827	110,855	-13%
Richmond and El Cerrito	25,698	17,943	42,512	35,981	59,787	46,040	44,895	36,670	172,892	136,634	-21%
Concord and Martinez	18,846	12,758	37,911	30,081	57,110	48,334	54,289	48,770	168,156	139,943	-17%
Walnut Creek	7,078	4,852	14,681	11,872	26,404	21,883	57,831	44,745	105,994	83,352	-21%
Danville and San Ramon	3,179	1,327	8,062	5,941	19,273	15,095	67,827	51,462	98,341	73,825	-25%
Antioch and Pittsburg	19,741	11,394	36,474	28,333	59,024	45,685	40,123	33,907	155,362	119,319	-23%
Vallejo and Benicia	14,716	9,609	24,026	19,975	34,793	27,913	26,973	23,613	100,508	81,110	-19%
Fairfield and Vacaville	24,122	14,448	42,208	33,934	58,029	47,575	38,490	33,378	162,849	129,335	-21%
Napa	9,511	6,298	15,693	13,168	21,643	16,635	14,163	11,208	61,010	47,309	-22%
St Helena	3,356	2,169	5,724	4,670	7,402	5,586	11,385	7,172	27,867	19,597	-30%
Petaluma and Rohnert Park	16,072	11,215	29,730	24,178	44,379	33,296	35,435	28,082	125,616	96,771	-23%
Santa Rosa and Sebastopol	24,337	16,981	41,521	36,293	55,046	42,280	42,675	32,275	163,579	127,829	-22%
Healdsburg and Cloverdale	8,237	6,165	14,621	11,876	19,245	13,944	15,777	10,954	57,880	42,939	-26%
Novato	4,056	2,321	8,978	7,017	13,227	10,564	15,970	13,077	42,231	32,979	-22%
San Rafael	9,277	6,644	15,212	12,813	22,293	18,376	33,041	25,755	79,823	63,588	-20%
Mill Valley and Sausalito	4,571	3,741	9,609	8,612	14,584	13,145	46,034	34,777	74,798	60,275	-19%
TOTAL	584,889	416,801	1,014,785	886,578	1,594,934	1,311,125	2,053,673	1,723,650	5,248,281	4,338,154	-17%

Table 5: Home-Based Work Trip Attractions by Household Income and Super-district of Workplace

Super-district	HBW Attractions (Employment End)										Percent
	Income Q1		Income Q2		Income Q2		Income Q3		Total		
	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	Difference
Greater Downtown San Francisco	69,473	46,001	113,748	97,348	173,033	144,417	256,454	201,684	612,708	489,450	-20%
San Francisco Richmond District	16,106	14,048	24,287	26,927	35,751	36,132	46,542	44,730	122,686	121,837	-1%
San Francisco Mission District	23,809	17,024	40,414	36,037	59,420	51,787	70,963	64,679	194,606	169,527	-13%
San Francisco Sunset District	7,218	4,350	10,102	8,173	11,591	11,471	12,101	13,925	41,012	37,919	-8%
Daly City and San Bruno	19,701	15,572	43,713	33,979	74,180	51,016	85,653	66,931	223,247	167,498	-25%
San Mateo and Burlingame	13,405	11,003	24,962	22,148	44,879	33,035	68,441	45,622	151,687	111,808	-26%
Redwood City and Menlo Park	15,158	13,343	28,901	29,810	47,023	46,097	79,638	65,025	170,720	154,275	-10%
Palo Alto and Los Altos	20,515	16,755	38,096	34,441	63,177	51,874	114,536	71,151	236,324	174,221	-26%
Sunnyvale and Mountain View	32,684	32,203	70,428	79,190	144,779	133,054	242,203	191,340	490,094	435,787	-11%
Cupertino and Saratoga	16,478	13,666	29,710	29,774	51,629	46,750	98,122	64,968	195,939	155,158	-21%
Central San Jose	22,132	17,345	40,268	36,646	66,085	58,314	92,773	80,519	221,258	192,824	-13%
Milpitas and East San Jose	16,224	11,344	29,830	25,797	54,589	42,123	69,712	57,460	170,355	136,724	-20%
South San Jose	6,905	5,279	14,391	11,219	28,797	18,101	48,289	25,091	98,382	59,690	-39%
Gilroy and Morgan Hill	6,250	3,744	9,877	8,204	17,912	13,578	21,247	18,185	55,286	43,711	-21%
Livermore and Pleasanton	13,680	11,593	25,553	25,518	46,035	39,047	57,742	54,568	143,010	130,726	-9%
Fremont and Union City	18,562	13,922	37,071	32,046	63,097	50,370	79,716	68,301	198,446	164,639	-17%
Hayward and San Leandro	28,024	16,365	52,901	34,632	75,131	52,065	69,800	65,054	225,856	168,116	-26%
Oakland and Alameda	47,401	27,726	67,209	55,911	91,828	80,095	100,631	102,291	307,069	266,023	-13%
Berkeley and Albany	24,998	15,887	31,723	30,595	39,852	41,129	47,340	51,498	143,913	139,109	-3%
Richmond and El Cerrito	16,485	7,947	24,713	16,679	36,540	23,324	31,824	28,604	109,562	76,554	-30%
Concord and Martinez	17,571	11,776	32,184	25,535	50,375	35,979	49,949	46,386	150,079	119,676	-20%
Walnut Creek	11,413	10,185	19,077	20,612	34,622	29,425	45,671	38,372	110,783	98,594	-11%
Danville and San Ramon	5,322	5,625	10,476	12,657	20,907	18,853	36,344	25,641	73,049	62,776	-14%
Antioch and Pittsburg	9,306	5,763	16,270	12,503	22,321	17,326	16,957	20,324	64,854	55,916	-14%
Vallejo and Benicia	10,216	5,987	16,148	12,140	22,023	16,627	17,718	19,150	66,105	53,904	-18%
Fairfield and Vacaville	17,110	10,791	26,725	21,778	35,579	29,965	25,727	33,082	105,141	95,616	-9%
Napa	9,051	4,966	14,625	10,590	19,295	14,305	16,365	16,063	59,336	45,924	-23%
St Helena	4,868	2,637	7,849	5,468	10,676	7,287	9,200	8,131	32,593	23,523	-28%
Petaluma and Rohnert Park	11,834	9,432	19,770	19,688	33,350	25,566	24,187	28,309	89,141	82,995	-7%
Santa Rosa and Sebastopol	26,704	15,987	46,511	32,797	59,630	40,436	43,884	42,610	176,729	131,830	-25%
Healdsburg and Cloverdale	5,392	3,330	8,007	6,526	8,485	8,315	7,989	8,445	29,873	26,616	-11%
Novato	4,633	2,943	9,667	6,279	13,573	8,626	13,577	11,205	41,450	29,053	-30%
San Rafael	9,399	6,878	17,269	13,779	22,866	19,646	26,652	24,890	76,186	65,193	-14%
Mill Valley and Sausalito	6,862	5,384	12,309	11,152	15,905	14,990	25,726	19,416	60,802	50,942	-16%
TOTAL	584,889	416,801	1,014,784	886,578	1,594,935	1,311,125	2,053,673	1,723,650	5,248,281	4,338,154	-17%

Table 6: Non-Work Trip Productions by Super-district

Super-district	Non-Work Productions (Residence End for Home-Based, Origin End for Non-Home-Based Trips)								Percent Difference
	Home-Based School		Home-Based Other		Non-Home-Based		Total		
	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	
Greater Downtown San Francisco	29,848	20,477	103,331	179,946	450,314	418,161	583,493	618,584	6%
San Francisco Richmond District	35,653	40,070	212,321	298,524	175,551	160,785	423,525	499,379	18%
San Francisco Mission District	92,826	84,991	312,705	449,231	216,290	225,312	621,821	759,534	22%
San Francisco Sunset District	61,407	34,800	140,472	196,631	78,409	79,122	280,288	310,553	11%
Daly City and San Bruno	80,811	85,552	364,475	434,565	291,786	234,538	737,072	754,655	2%
San Mateo and Burlingame	68,050	52,636	269,720	323,617	207,192	181,694	544,962	557,947	2%
Redwood City and Menlo Park	62,298	61,179	281,238	348,164	200,074	207,448	543,610	616,791	13%
Palo Alto and Los Altos	81,635	48,837	225,696	277,982	252,034	240,987	559,365	567,806	2%
Sunnyvale and Mountain View	55,550	61,271	299,692	361,299	368,385	451,154	723,627	873,724	21%
Cupertino and Saratoga	126,599	98,321	424,570	506,684	274,468	303,768	825,637	908,773	10%
Central San Jose	126,910	89,306	345,103	433,038	275,914	342,121	747,927	864,465	16%
Milpitas and East San Jose	119,635	121,613	483,747	564,649	217,961	237,333	821,343	923,595	12%
South San Jose	62,788	59,764	291,718	337,406	145,018	125,152	499,524	522,322	5%
Gilroy and Morgan Hill	34,708	30,859	125,815	147,786	68,964	70,750	229,487	249,395	9%
Livermore and Pleasanton	57,961	54,065	184,314	276,842	164,759	202,905	407,034	533,812	31%
Fremont and Union City	103,640	82,474	330,926	475,652	202,259	266,075	636,825	824,201	29%
Hayward and San Leandro	127,575	94,310	356,060	550,410	240,519	329,892	724,154	974,612	35%
Oakland and Alameda	149,678	145,455	428,103	699,776	326,809	412,159	904,590	1,257,390	39%
Berkeley and Albany	77,894	50,286	147,751	238,641	169,102	214,705	394,747	503,632	28%
Richmond and El Cerrito	75,217	80,918	250,934	372,126	141,796	153,730	467,947	606,774	30%
Concord and Martinez	78,174	68,621	241,729	347,062	177,244	221,828	497,147	637,511	28%
Walnut Creek	50,821	38,077	166,584	238,759	136,083	164,050	353,488	440,886	25%
Danville and San Ramon	36,387	34,012	138,464	184,583	80,949	94,943	255,800	313,538	23%
Antioch and Pittsburg	84,228	85,842	245,453	349,615	101,149	148,765	430,830	584,222	36%
Vallejo and Benicia	47,283	51,376	152,552	224,950	84,850	117,545	284,685	393,871	38%
Fairfield and Vacaville	95,892	89,625	248,005	373,766	146,836	196,700	490,733	660,091	35%
Napa	32,129	29,008	93,816	135,533	68,602	85,830	194,547	250,371	29%
St Helena	9,423	10,927	40,481	57,498	28,712	30,183	78,616	98,608	25%
Petaluma and Rohnert Park	53,783	48,746	174,122	247,665	99,775	141,139	327,680	437,550	34%
Santa Rosa and Sebastopol	86,039	71,219	234,290	344,560	178,720	238,964	499,049	654,743	31%
Healdsburg and Cloverdale	22,659	28,044	84,704	119,489	33,715	50,632	141,078	198,165	40%
Novato	13,603	17,570	60,640	87,117	42,991	47,327	117,234	152,014	30%
San Rafael	26,266	28,729	112,371	166,409	91,422	102,496	230,059	297,634	29%
Mill Valley and Sausalito	27,483	22,029	98,380	150,436	82,011	80,263	207,874	252,728	22%
TOTAL	2,294,853	2,021,009	7,670,282	10,500,411	5,820,663	6,578,456	15,785,798	19,099,876	21%

Table 7: Non-Work Attractions by Purpose and Super-district

Super-district	Non-Work Attractions (Activity End for Home-Based, Destination End for Non-Home-Based Trips)								Percent Difference
	Home-Based School		Home-Based Other		Non-Home-Based		Total		
	4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM	
Greater Downtown San Francisco	22,809	23,008	299,812	491,481	449,973	422,540	772,594	937,029	21%
San Francisco Richmond District	44,961	34,599	198,101	285,580	175,513	160,615	418,575	480,794	15%
San Francisco Mission District	94,876	84,938	246,399	387,357	216,062	222,754	557,337	695,049	25%
San Francisco Sunset District	39,292	53,700	106,282	156,545	78,352	79,008	223,926	289,253	29%
Daly City and San Bruno	98,095	75,197	358,736	367,495	291,631	234,354	748,462	677,046	-10%
San Mateo and Burlingame	58,222	53,051	276,723	287,953	207,021	181,556	541,966	522,560	-4%
Redwood City and Menlo Park	70,932	50,865	263,909	300,048	201,981	205,636	536,822	556,549	4%
Palo Alto and Los Altos	54,994	66,249	313,533	319,954	252,229	236,727	620,756	622,930	0%
Sunnyvale and Mountain View	65,749	49,410	415,320	483,927	368,826	454,354	849,895	987,691	16%
Cupertino and Saratoga	103,920	103,515	421,030	525,415	274,684	312,092	799,634	941,022	18%
Central San Jose	101,640	105,341	360,209	574,230	276,257	347,544	738,106	1,027,115	39%
Milpitas and East San Jose	146,907	109,279	330,586	435,716	218,219	233,074	695,712	778,069	12%
South San Jose	79,948	56,953	227,875	256,139	145,161	123,612	452,984	436,704	-4%
Gilroy and Morgan Hill	39,403	29,293	105,586	131,863	69,358	68,567	214,347	229,723	7%
Livermore and Pleasanton	61,103	50,021	202,511	288,448	162,161	202,524	425,775	540,993	27%
Fremont and Union City	113,675	87,881	280,768	426,320	205,009	262,519	599,452	776,720	30%
Hayward and San Leandro	121,834	108,165	329,081	581,440	244,280	336,293	695,195	1,025,898	48%
Oakland and Alameda	159,964	133,749	408,169	685,008	325,091	412,287	893,224	1,231,044	38%
Berkeley and Albany	56,767	61,636	204,759	339,543	167,587	220,207	429,113	621,386	45%
Richmond and El Cerrito	88,102	71,151	237,245	288,512	142,934	152,673	468,281	512,336	9%
Concord and Martinez	74,064	68,239	283,148	366,607	177,038	226,666	534,250	661,512	24%
Walnut Creek	42,712	44,922	201,135	252,212	133,701	164,334	377,548	461,468	22%
Danville and San Ramon	41,307	32,077	124,558	140,448	79,907	91,546	245,772	264,071	7%
Antioch and Pittsburg	94,333	80,107	185,779	306,596	101,088	144,790	381,200	531,493	39%
Vallejo and Benicia	55,755	48,156	149,426	218,614	85,914	116,799	291,095	383,569	32%
Fairfield and Vacaville	94,582	88,335	247,100	357,247	146,019	193,174	487,701	638,756	31%
Napa	30,693	30,734	93,602	145,033	68,910	85,669	193,205	261,436	35%
St Helena	10,748	9,171	41,671	40,439	28,557	28,626	80,976	78,236	-3%
Petaluma and Rohnert Park	56,969	49,275	162,243	226,555	100,627	137,352	319,839	413,182	29%
Santa Rosa and Sebastopol	74,702	75,254	271,345	391,889	177,156	243,071	523,203	710,214	36%
Healdsburg and Cloverdale	27,066	24,181	54,893	88,077	34,727	48,438	116,686	160,696	38%
Novato	17,335	14,545	49,673	76,764	41,952	46,897	108,960	138,206	27%
San Rafael	29,695	25,697	105,259	154,503	90,751	101,921	225,705	282,121	25%
Mill Valley and Sausalito	21,728	22,315	113,816	122,453	81,987	80,237	217,531	225,005	3%
TOTAL	2,294,882	2,021,009	7,670,282	10,500,411	5,820,663	6,578,456	15,785,827	19,099,876	21%

As shown in Table 8, when the trips from both commercial and non-commercial sources are combined, the total number of trips in the four-step model is 24.4 million; the total number of trips in the activity-based model is 25.6 million. The overall deviation is less than five percent.

Table 8: All Trips, Commercial and Non-Commercial

Trip Purpose	Number of Trips		Diff.	Pct. Diff
	4-step	ABM		
Home-Based Work	5,248,281	4,338,154	-910,127	-17.3%
Home-Based School	2,294,853	2,021,009	-273,844	-11.9%
Home-Based Other	7,670,282	10,500,411	2,830,129	36.9%
Non-Home-Based	5,820,663	6,578,456	757,793	13.0%
Heavy Truck	273,991	273,991	0	0.0%
Small Truck	3,130,387	1,878,232	-1,252,155	-40.0%
Total	24,438,457	25,590,253	1,151,796	4.7%

4 Trip Distribution

This section presents the results for the number of trips between counties and the length of trips for each trip-based model purpose.

In the trip based model, trip productions are matched with trip attractions according to a gravity model. The basis of this aggregate model is that the rate of travel of residents from a production zone to an attraction zone should decline with the impedance between them (drive time, or mode-weighted travel time for home-based work) and increase with the total number of attractions at the destination zone. The trip-based gravity model includes a large number of k-factors (constants for super-district to super-district exchanges) in order to achieve a close fit with the observed data.

In the activity-based model, primary tour destinations are selected for each tour using a multinomial logit model with size terms. On an aggregate level, this logit model is structurally equivalent to a gravity model with a negative exponential impedance function, but the simulation application allows for the destination choices to be made with more information about the individual decision context, such as the expected utility (logsum) from the mode choice model specific to an individual's prospective travel between locations. Intermediate stops are located according to a similar model, with stops tending to cluster near the primary tour origins and destinations. Because of the additional information the tour structure provides the destination choice model, k-factors are not necessary in the activity-based model.

Table 9 shows the number of home-based work trips between each county for each income quartile in the trip-based model, activity-based model, and home/workplace locations from the Census Transportation Planning Package (CTPP). All three trip tables are very similar. Recall that the models should contain fewer home-based-work trips than home/work locations in the CTPP because it reflects intermediate stops and workers who do not travel to work on a typical weekday. The only cases where the activity-based model diverges significantly from the four-step and Census tables are in the intra-county cells. Specifically, the activity-based model includes more home-based work trips that cross county lines. To avoid over-fitting the model in calibration, the model development team decided not to introduce intra-county constants (similar to k-factors) and focused on the trip lengths of work tours to retain sensitivity in the model.

Table 10 shows the county-to-county trip tables for the other purposes. As discussed in section 3 *Trip Generation*, the activity-based model includes more home-based other and non-home-based travel – please see that section for a detailed explanation. Given the differences in the total number of trips, the trip distributions are very similar: the correlation between the home-based other table cells is greater than 0.99.

Trip length frequency distributions are shown for each purpose in Figure 1 through Figure 9. The trip- and activity-based models are nearly identical, although there are some deviations between the share of very short and medium-length home-based-other and non-home-based trips.

Table 9: County-to-County Home-Based Work Trip Distribution

Production	Attraction	Income Q1			Income Q2			Income Q3			Income Q4			Total		
		Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM
SF	SF	74,116	74,797	54,447	105,360	107,465	107,383	138,781	142,274	128,575	180,794	186,082	176,930	499,051	510,618	467,334
SF	SM	7,440	6,083	7,566	12,468	11,452	13,376	22,881	23,238	18,006	31,277	31,304	18,747	74,066	72,077	57,695
SF	SC	2,027	1,188	1,674	4,173	4,318	2,464	6,457	5,783	3,582	14,512	14,242	2,216	27,169	25,532	9,937
SF	ALA	3,760	2,720	2,169	5,601	4,616	5,658	10,829	10,274	13,006	15,145	15,605	19,627	35,335	33,215	40,458
SF	CC	573	471	443	1,324	1,188	961	2,236	2,091	2,419	3,542	4,113	5,026	7,675	7,864	8,850
SF	SOL	25	14	19	91	55	25	222	169	163	344	308	609	682	547	816
SF	NAP	40	17	4	0	23	12	70	47	43	369	276	306	479	364	365
SF	SON	294	42	12	165	111	10	335	117	95	620	635	1,016	1,414	905	1,133
SF	MAR	936	959	694	2,064	1,721	1,509	3,160	2,942	3,482	4,105	3,940	6,001	10,265	9,562	11,686
SM	SF	8,628	7,786	3,779	18,670	20,723	13,535	38,281	39,893	33,652	53,895	56,236	50,287	119,474	124,638	101,251
SM	SM	30,415	30,667	21,019	61,858	61,546	50,208	102,378	100,283	68,875	136,551	136,719	97,475	331,202	329,215	237,576
SM	SC	5,923	6,208	8,768	12,867	13,718	17,661	24,084	25,259	26,714	54,988	62,601	35,315	97,862	107,786	88,457
SM	ALA	1,748	1,530	1,134	3,482	3,384	3,982	6,981	6,758	10,947	14,307	16,035	22,445	26,518	27,707	38,508
SM	CC	276	248	99	353	322	364	1,089	1,054	1,474	1,364	1,512	3,574	3,082	3,136	5,511
SM	SOL	94	25	4	72	50	5	67	49	69	314	279	335	547	402	413
SM	NAP	28	16	0	0	9	0	22	14	21	83	61	145	133	101	166
SM	SON	42	29	0	127	130	2	322	282	53	310	326	468	801	768	523
SM	MAR	125	114	123	232	217	400	430	372	1,421	613	625	2,848	1,400	1,328	4,792
SC	SF	810	986	33	1,903	1,989	250	3,978	4,670	2,266	7,034	6,232	9,519	13,725	13,877	12,066
SC	SM	4,551	3,934	1,818	9,507	8,463	5,689	18,257	16,385	15,486	37,004	33,863	36,849	69,319	62,646	59,842
SC	SC	104,312	104,739	72,959	189,745	191,461	175,554	343,687	346,428	281,642	541,564	541,124	430,196	1,179,308	1,183,752	960,349
SC	ALA	4,289	3,776	1,878	9,145	8,436	6,585	17,884	16,941	18,327	29,029	29,267	49,072	60,347	58,421	75,860
SC	CC	481	387	25	835	713	190	1,209	1,030	1,110	2,419	2,240	4,334	4,944	4,370	5,659
SC	SOL	85	41	0	199	128	0	319	210	30	452	333	368	1,055	712	398
SC	NAP	0	4	0	59	37	0	0	11	4	124	81	111	183	134	115
SC	SON	164	57	0	80	66	0	229	163	7	449	191	102	922	476	109
SC	MAR	94	69	0	282	218	4	235	185	93	571	495	642	1,182	967	739
ALA	SF	16,104	17,800	13,796	23,427	27,356	21,965	35,454	38,794	33,549	43,236	50,816	41,025	118,221	134,766	110,333
ALA	SM	4,984	5,369	7,036	10,597	9,471	11,498	18,723	16,863	19,025	22,369	18,897	17,072	56,673	50,600	54,631
ALA	SC	5,578	6,283	14,358	17,235	18,540	25,288	39,049	41,366	43,470	54,659	56,199	35,819	116,521	122,388	118,936
ALA	ALA	111,206	108,651	67,376	160,191	158,168	127,014	215,212	215,558	158,168	214,226	212,685	185,241	700,835	695,062	537,797
ALA	CC	6,368	5,885	6,130	10,207	9,685	9,268	20,371	20,157	16,257	21,284	22,015	26,776	58,230	57,742	58,429
ALA	SOL	332	202	91	647	440	145	1,114	852	574	1,195	882	2,338	3,288	2,375	3,148
ALA	NAP	24	34	18	134	91	37	167	108	162	260	176	813	585	411	1,030
ALA	SON	257	179	10	216	209	8	620	537	94	581	533	794	1,674	1,458	906
ALA	MAR	973	781	784	1,473	1,301	1,058	1,839	1,536	2,159	2,192	1,835	3,530	6,477	5,453	7,531
CC	SF	5,858	7,787	4,633	15,381	16,995	11,953	25,224	28,440	23,397	37,677	39,756	24,528	84,140	92,977	64,510
CC	SM	1,152	1,268	1,252	2,339	2,350	2,597	5,034	4,995	4,817	6,659	5,748	4,445	15,184	14,361	13,109
CC	SC	935	1,266	1,761	2,243	2,750	3,332	4,479	5,216	6,677	9,666	9,637	4,594	17,323	18,869	16,364
CC	ALA	12,526	12,651	9,807	30,103	31,494	26,719	51,762	53,623	47,239	68,096	69,277	55,848	162,487	167,045	139,613
CC	CC	50,138	48,696	28,872	81,530	80,323	63,435	121,492	121,157	84,589	133,641	133,568	106,918	386,801	383,744	283,812
CC	SOL	1,101	800	619	2,411	1,932	1,710	4,199	3,563	4,689	4,234	3,598	10,348	11,945	9,893	17,367

Production	Attraction	Income Q1			Income Q2			Income Q3			Income Q4			Total		
		Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM	Census	4-step	ABM
CC	NAP	74	168	79	336	547	229	922	790	997	738	646	2,915	2,070	2,151	4,221
CC	SON	109	87	25	339	375	60	453	438	384	338	333	1,786	1,239	1,233	2,256
CC	MAR	2,057	1,820	1,180	3,102	2,875	2,229	3,629	3,377	4,233	2,780	2,401	4,181	11,568	10,473	11,821
SOL	SF	1,355	1,811	970	3,962	4,223	3,418	7,266	6,543	5,745	5,603	3,868	2,427	18,186	16,445	12,561
SOL	SM	335	348	275	1,124	1,186	619	1,603	1,486	1,093	1,303	1,042	318	4,365	4,062	2,306
SOL	SC	433	874	301	605	890	619	655	858	921	791	872	155	2,484	3,493	1,997
SOL	ALA	1,680	2,214	1,736	5,295	5,691	5,348	8,582	8,754	8,387	5,827	5,900	3,344	21,384	22,559	18,815
SOL	CC	2,834	3,432	4,307	7,956	8,336	10,396	15,473	16,027	13,608	10,874	11,587	7,769	37,137	39,382	36,078
SOL	SOL	28,237	25,329	15,000	41,102	37,983	29,716	50,196	48,615	37,371	36,224	35,279	34,680	155,759	147,206	116,765
SOL	NAP	2,300	2,890	809	3,110	4,779	2,209	4,465	6,269	4,581	3,009	4,178	4,942	12,884	18,116	12,540
SOL	SON	499	447	135	1,121	1,224	363	1,488	1,459	1,253	919	985	1,990	4,027	4,115	3,741
SOL	MAR	1,295	1,493	502	1,968	1,922	1,227	3,019	2,813	2,539	1,851	1,753	1,376	8,133	7,980	5,642
NAP	SF	207	394	196	321	460	582	684	828	1,026	980	949	330	2,192	2,631	2,134
NAP	SM	84	131	73	197	249	128	102	109	221	505	403	55	888	892	477
NAP	SC	22	76	62	166	259	84	130	189	125	249	341	15	567	865	286
NAP	ALA	110	197	289	448	578	925	650	753	1,526	768	864	416	1,976	2,392	3,156
NAP	CC	366	516	678	823	996	1,473	986	1,157	2,008	1,075	1,309	783	3,250	3,978	4,943
NAP	SOL	526	737	725	1,484	1,577	1,606	2,553	2,812	2,328	1,229	1,481	1,739	5,792	6,607	6,396
NAP	NAP	11,154	10,313	5,695	16,840	15,780	11,371	21,867	21,018	12,066	18,998	18,381	11,605	68,859	65,492	40,735
NAP	SON	339	359	462	686	1,030	1,029	1,456	1,574	1,989	1,163	1,525	3,056	3,644	4,488	6,535
NAP	MAR	109	145	281	460	488	637	587	604	936	291	295	390	1,447	1,531	2,244
SON	SF	860	2,519	966	2,686	4,660	2,807	4,911	7,015	4,070	5,565	12,592	911	14,022	26,786	8,752
SON	SM	226	257	285	491	2,091	658	873	1,632	709	837	1,346	121	2,427	5,326	1,773
SON	SC	154	232	105	237	321	130	800	1,125	194	718	757	26	1,909	2,435	455
SON	ALA	386	380	280	915	943	955	1,332	1,312	1,586	1,083	917	401	3,716	3,552	3,222
SON	CC	205	207	380	418	378	974	797	775	1,351	1,235	1,176	368	2,655	2,537	3,073
SON	SOL	223	156	245	654	474	579	1,223	1,063	1,041	672	580	758	2,772	2,273	2,623
SON	NAP	624	444	982	1,458	1,117	2,158	1,674	1,544	3,496	1,777	1,461	2,509	5,533	4,565	9,146
SON	SON	43,469	42,264	27,949	71,052	69,701	57,172	95,094	94,549	69,305	69,080	68,234	63,819	278,695	274,748	218,245
SON	MAR	2,743	2,187	3,132	8,026	6,187	6,931	11,830	9,655	7,771	8,869	6,824	2,418	31,468	24,852	20,250
MAR	SF	2,795	2,752	2,425	6,305	4,687	6,607	11,725	11,343	11,598	32,581	29,533	19,164	53,406	48,315	39,792
MAR	SM	146	181	585	538	768	1,190	787	1,088	1,932	3,099	4,410	2,464	4,570	6,447	6,172
MAR	SC	62	88	197	230	336	262	537	711	513	975	1,098	362	1,804	2,234	1,334
MAR	ALA	514	524	495	1,102	1,156	1,641	1,947	1,969	3,626	4,184	4,679	5,421	7,747	8,328	11,184
MAR	CC	249	274	309	680	784	967	1,239	1,322	2,087	2,651	3,225	3,799	4,819	5,605	7,161
MAR	SOL	68	56	58	257	237	141	288	273	331	659	707	1,064	1,272	1,273	1,594
MAR	NAP	84	59	8	107	91	39	200	172	228	322	306	854	713	628	1,129
MAR	SON	743	617	121	1,192	1,425	382	2,197	2,361	1,139	2,469	3,298	6,353	6,601	7,702	7,993
MAR	MAR	13,419	13,353	8,498	23,450	24,315	17,219	31,152	30,864	20,641	43,214	47,789	34,125	111,235	116,321	80,483
Total		589,907	584,890	416,002	1,010,039	1,014,783	886,926	1,584,534	1,594,933	1,311,375	2,027,259	2,053,671	1,723,853	5,211,739	5,248,282	4,338,154

Table 10: County-to-County Non-Work Trip Distribution

Production	Attraction	Home-Based School		Home-Based Other		Non-Home-Based		Total	
		4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM
SF	SF	195,958	165,340	666,094	1,027,871	777,223	779,275	1,639,275	1,972,486
SF	SM	2,140	11,575	79,031	65,988	84,070	51,796	165,241	129,359
SF	SC	662	294	1,926	1,238	7,315	2,883	9,903	4,415
SF	ALA	2,488	2,190	10,705	21,809	30,303	31,367	43,496	55,366
SF	CC	245	551	3,897	2,917	9,496	7,310	13,638	10,778
SF	SOL	10	52	323	106	1,126	715	1,459	873
SF	NAP	9	8	58	11	447	162	514	181
SF	SON	178	19	251	51	1,294	731	1,723	801
SF	MAR	247	309	6,543	4,341	9,289	9,141	16,079	13,791
SM	SF	15,349	21,387	117,007	153,572	88,122	53,313	220,478	228,272
SM	SM	205,283	157,837	723,730	803,758	527,877	486,761	1,456,890	1,448,356
SM	SC	5,444	15,098	63,397	116,168	60,644	58,077	129,485	189,343
SM	ALA	937	4,576	7,895	29,877	15,334	21,996	24,166	56,449
SM	CC	57	325	1,768	1,618	3,188	1,945	5,013	3,888
SM	SOL	2	25	136	59	528	175	666	259
SM	NAP	13	2	23	6	293	40	329	48
SM	SON	139	14	39	14	886	165	1,064	193
SM	MAR	25	103	1,437	1,274	2,179	1,208	3,641	2,585
SC	SF	687	200	9,422	1,515	7,438	3,254	17,547	4,969
SC	SM	1,649	5,790	71,112	49,279	64,588	57,828	137,349	112,897
SC	SC	584,769	494,291	2,077,126	2,528,033	1,489,864	1,655,235	4,151,759	4,677,559
SC	ALA	4,966	9,448	33,852	49,128	32,997	51,733	71,815	110,309
SC	CC	82	226	4,258	840	3,970	2,765	8,310	3,831
SC	SOL	1	7	137	15	636	158	774	180
SC	NAP	33	2	49	2	511	30	593	34
SC	SON	362	1	88	2	1,819	48	2,269	51
SC	MAR	12	6	297	30	920	214	1,229	250
ALA	SF	2,689	3,773	29,052	64,138	23,297	29,086	55,038	96,997
ALA	SM	884	2,308	21,541	29,743	15,102	20,326	37,527	52,377
ALA	SC	10,517	8,845	31,448	78,310	34,335	55,016	76,300	142,171
ALA	ALA	494,615	398,982	1,306,508	1,994,140	973,926	1,243,805	2,775,049	3,636,927
ALA	CC	3,767	12,081	55,237	71,776	47,958	70,195	106,962	154,052
ALA	SOL	59	265	1,549	931	3,318	2,403	4,926	3,599
ALA	NAP	60	41	230	105	1,149	464	1,439	610
ALA	SON	556	31	224	48	2,132	466	2,912	545
ALA	MAR	196	264	1,366	2,130	2,232	3,975	3,794	6,369
CC	SF	2,310	2,043	12,476	26,743	9,405	7,201	24,191	35,987
CC	SM	390	647	2,123	2,917	3,634	2,432	6,147	5,996
CC	SC	3,312	1,312	1,455	3,168	5,202	3,881	9,969	8,361
CC	ALA	12,375	22,482	62,273	204,534	44,904	74,288	119,552	301,304
CC	CC	319,278	276,287	947,695	1,224,751	556,239	672,132	1,823,212	2,173,170
CC	SOL	869	3,632	13,309	20,963	10,852	15,241	25,030	39,836
CC	NAP	246	235	1,226	1,382	2,437	1,582	3,909	3,199
CC	SON	1,529	125	414	282	2,181	763	4,124	1,170
CC	MAR	209	707	2,191	7,405	2,367	5,796	4,767	13,908
SOL	SF	752	604	1,575	2,238	1,304	1,436	3,631	4,278
SOL	SM	185	64	242	282	833	432	1,260	778
SOL	SC	1,677	85	40	150	1,540	424	3,257	659
SOL	ALA	1,178	2,133	2,461	7,874	2,799	4,012	6,438	14,019

Production	Attraction	Home-Based School		Home-Based Other		Non-Home-Based		Total	
		4-step	ABM	4-step	ABM	4-step	ABM	4-step	ABM
SOL	CC	1,759	5,254	15,443	38,268	9,141	17,052	26,343	60,574
SOL	SOL	142,427	129,422	377,653	534,590	212,166	279,049	732,246	943,061
SOL	NAP	722	2,860	1,720	13,274	1,348	8,879	3,790	25,013
SOL	SON	920	296	395	770	1,391	1,363	2,706	2,429
SOL	MAR	717	283	1,026	1,270	1,164	1,598	2,907	3,151
NAP	SF	102	19	370	351	421	286	893	656
NAP	SM	26	13	72	46	434	98	532	157
NAP	SC	236	9	26	18	949	64	1,211	91
NAP	ALA	94	131	488	1,125	871	816	1,453	2,072
NAP	CC	68	390	1,806	2,816	1,777	1,878	3,651	5,084
NAP	SOL	251	2,528	2,420	16,135	1,522	9,285	4,193	27,948
NAP	NAP	40,343	35,854	124,342	164,806	84,202	98,527	248,887	299,187
NAP	SON	312	960	4,394	7,065	6,645	4,395	11,351	12,420
NAP	MAR	9	31	379	669	492	664	880	1,364
SON	SF	443	187	1,631	1,586	1,450	1,484	3,524	3,257
SON	SM	85	43	413	215	1,504	445	2,002	703
SON	SC	774	22	199	27	3,373	149	4,346	198
SON	ALA	186	164	513	972	1,778	978	2,477	2,114
SON	CC	25	138	684	921	1,512	1,072	2,221	2,131
SON	SOL	11	231	539	1,807	939	1,465	1,489	3,503
SON	NAP	133	792	7,268	5,538	6,568	4,044	13,969	10,374
SON	SON	156,709	145,611	478,725	691,129	292,655	413,835	928,089	1,250,575
SON	MAR	88	821	3,144	9,519	2,432	7,263	5,664	17,603
MAR	SF	1,093	2,692	12,914	42,949	11,241	9,582	25,248	55,223
MAR	SM	15	836	1,346	3,268	2,593	1,428	3,954	5,532
MAR	SC	50	84	83	132	1,517	241	1,650	457
MAR	ALA	89	1,346	817	11,300	1,215	4,835	2,121	17,481
MAR	CC	67	1,244	986	10,468	1,386	5,660	2,439	17,372
MAR	SOL	18	329	402	1,255	844	1,482	1,264	3,066
MAR	NAP	8	111	146	348	511	567	665	1,026
MAR	SON	1,698	1,653	2,574	7,160	3,501	7,095	7,773	15,908
MAR	MAR	65,720	60,033	252,122	327,082	193,615	199,196	511,457	586,311
Total		2,294,598	2,021,009	7,670,276	10,500,411	5,820,660	6,578,456	15,785,534	19,099,876

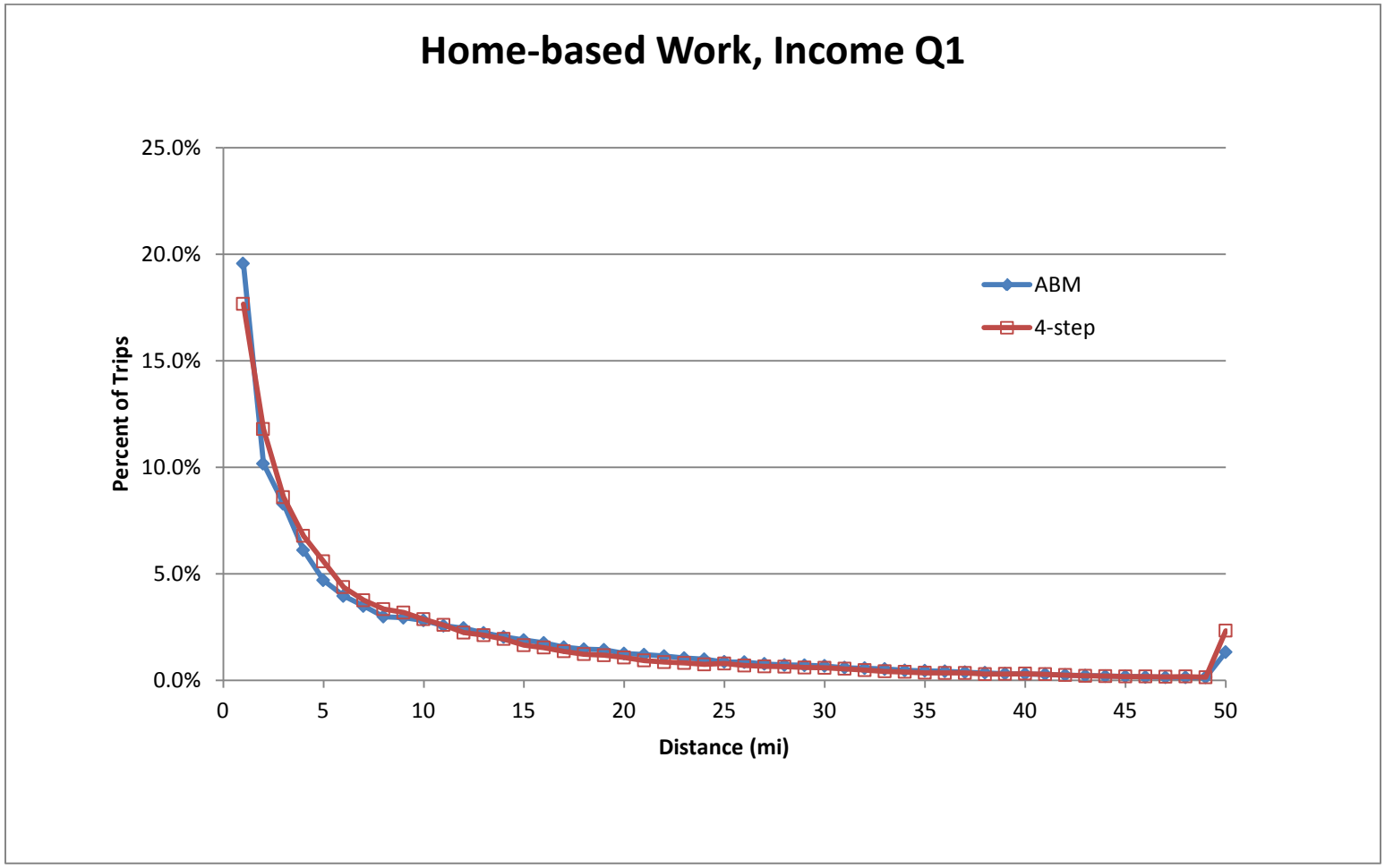

Figure 1: Home-Based Work Trip Length Frequency Distribution, Income Quartile 1

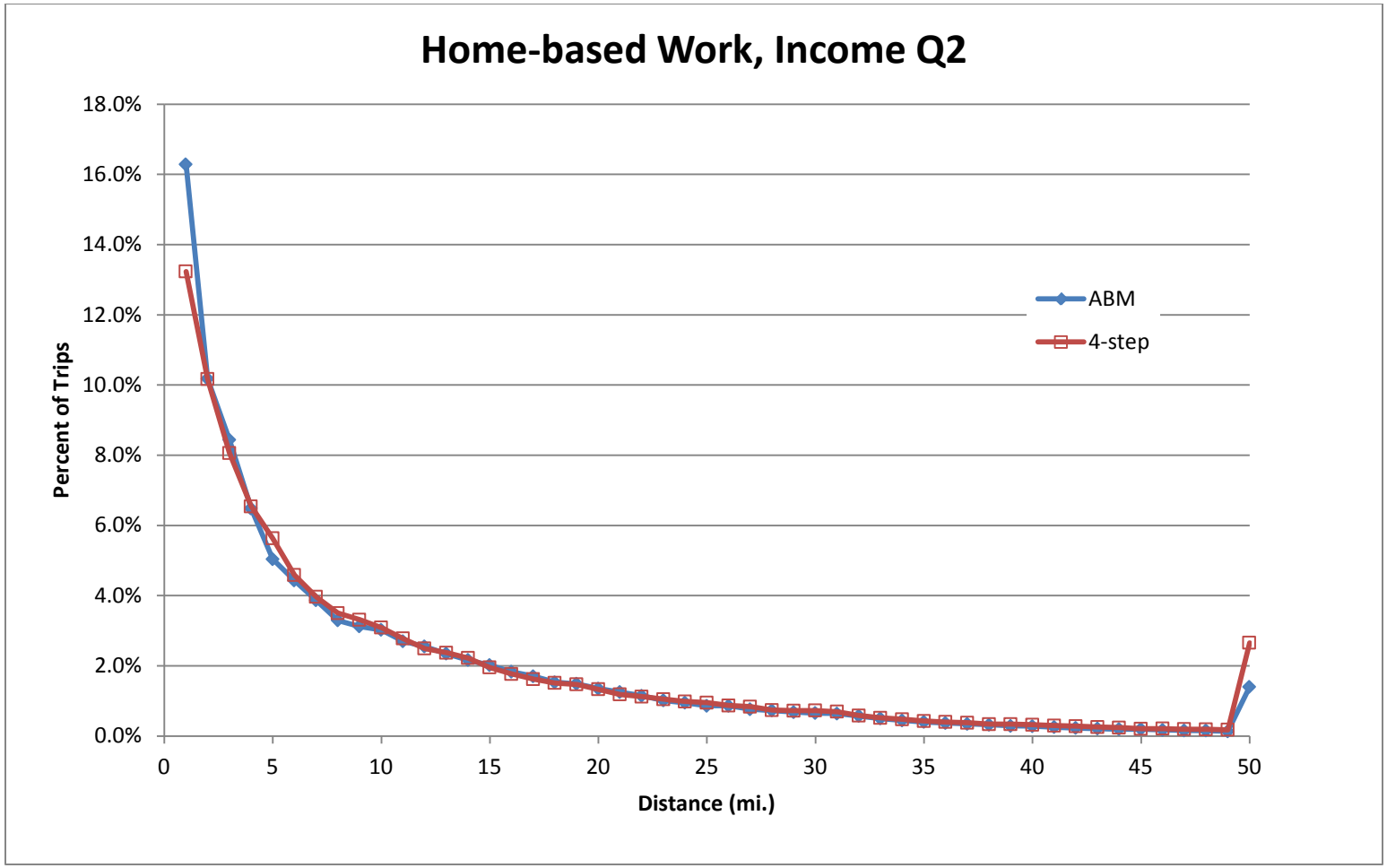

Figure 2: Home-Based Work Trip Length Frequency Distribution, Income Quartile 2

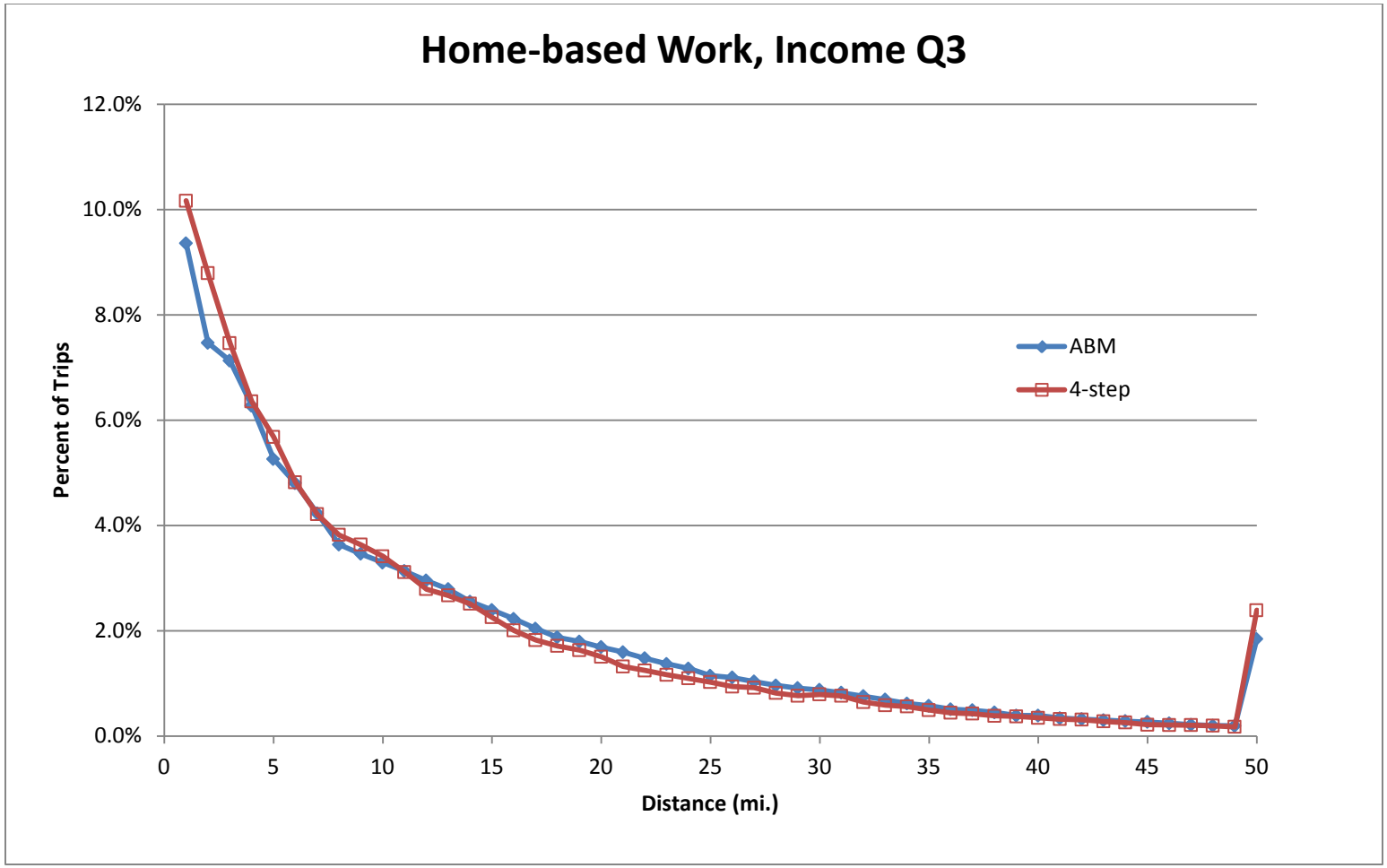

Figure 3: Home-Based Work Trip Length Frequency Distribution, Income Quartile 3

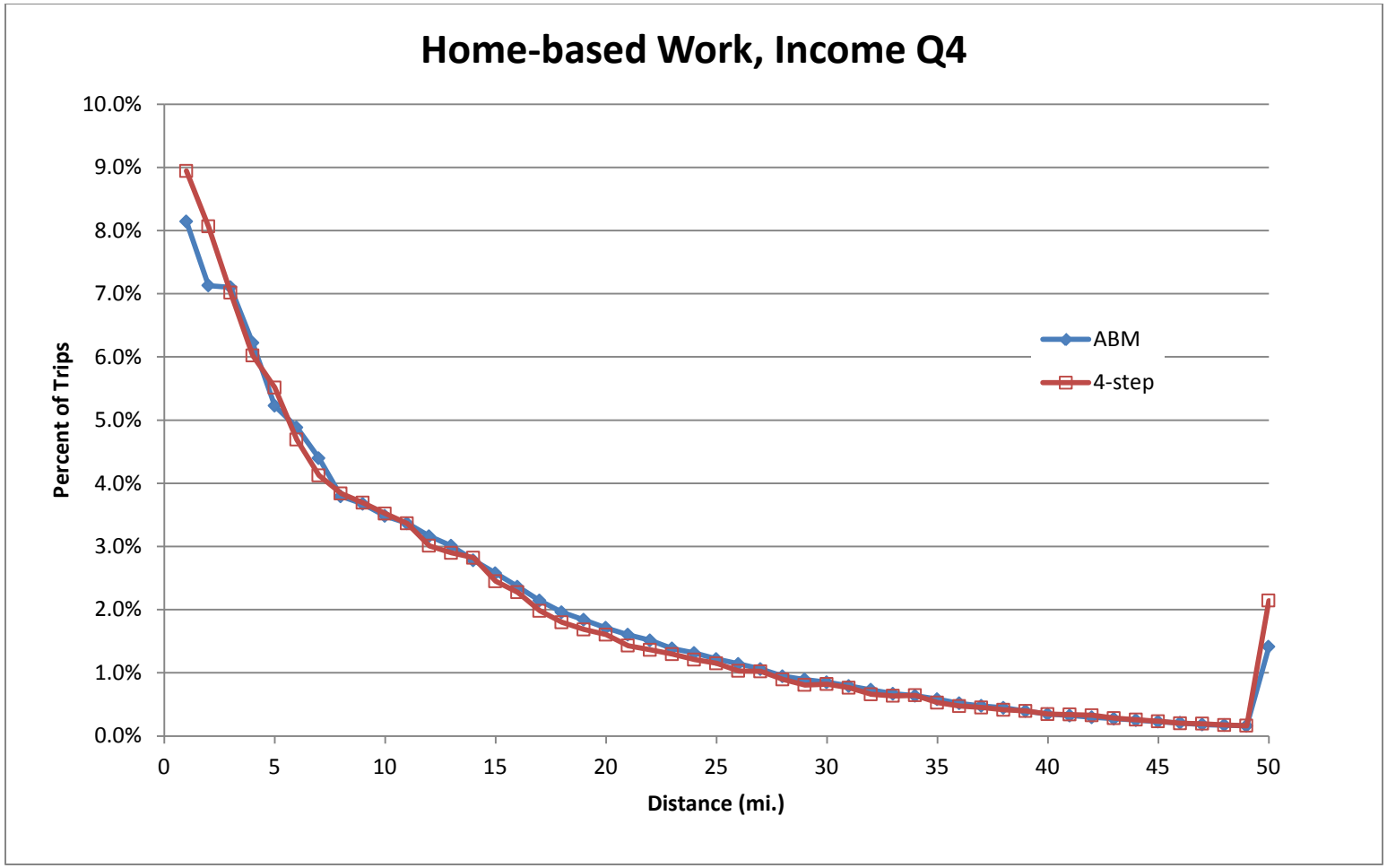

Figure 4: Home-Based Work Trip Length Frequency Distribution, Income Quartile 4

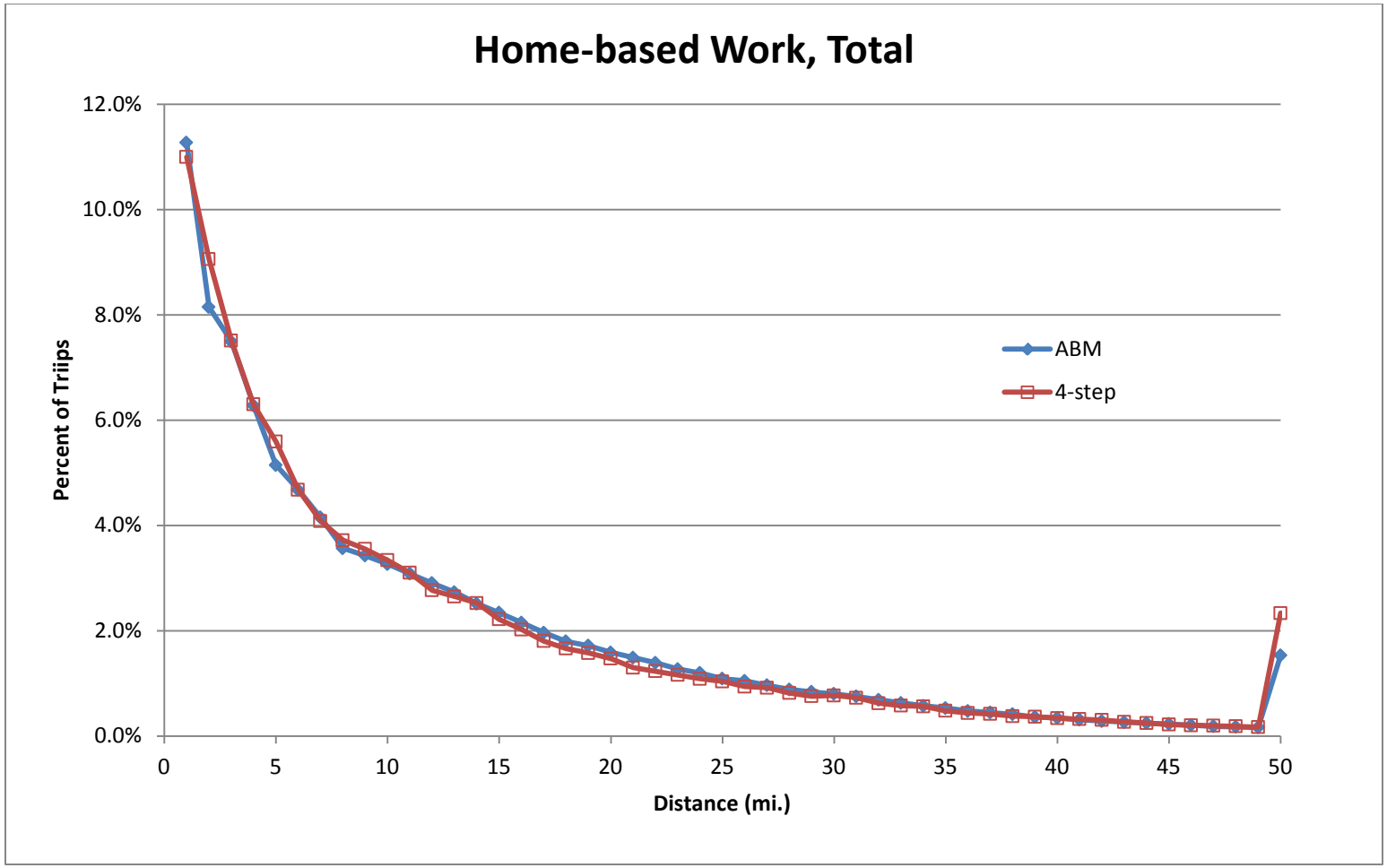

Figure 5: Home-Based Work Trip Length Frequency Distribution, Total

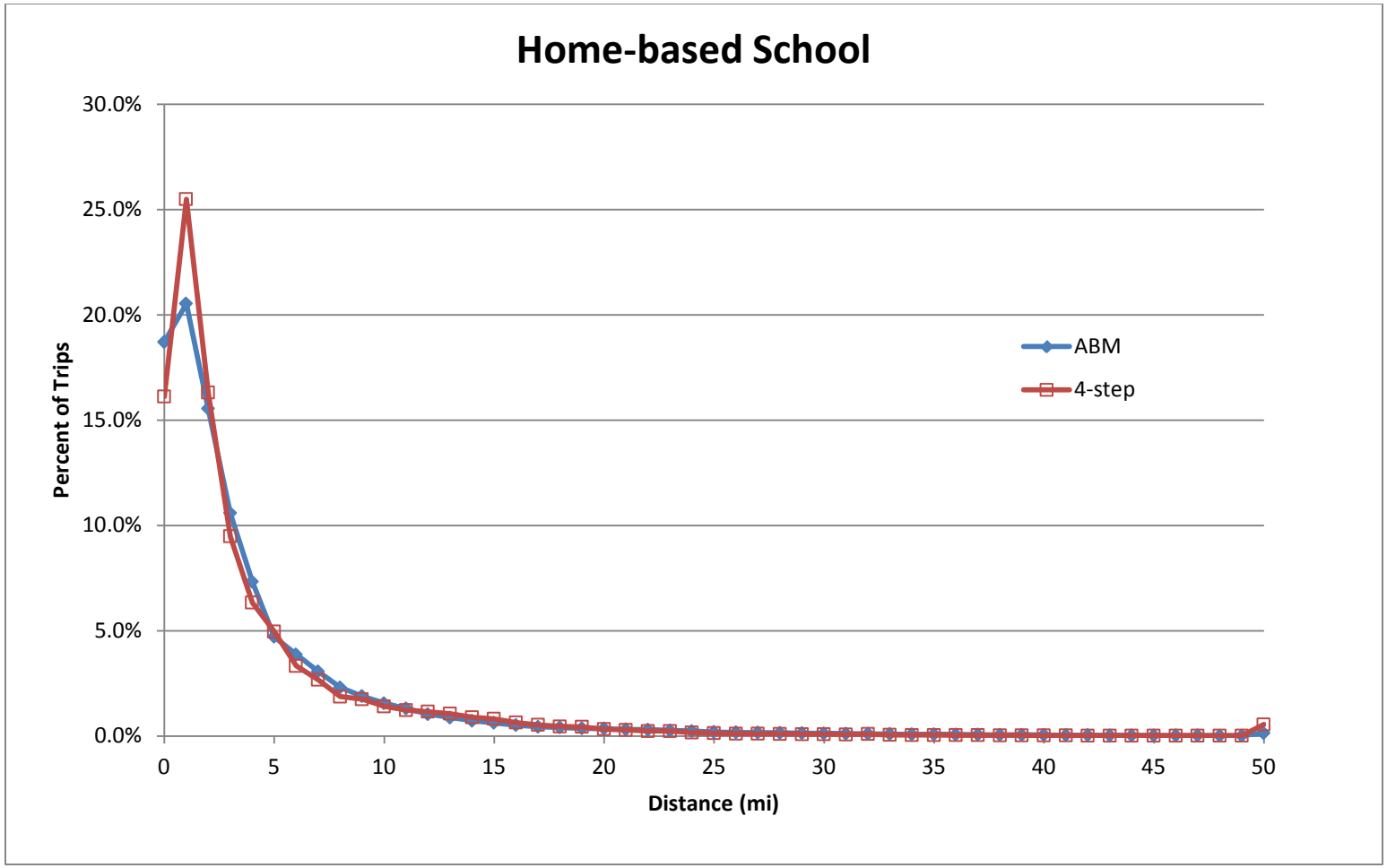

Figure 6: Home-Based School Trip Length Frequency Distribution

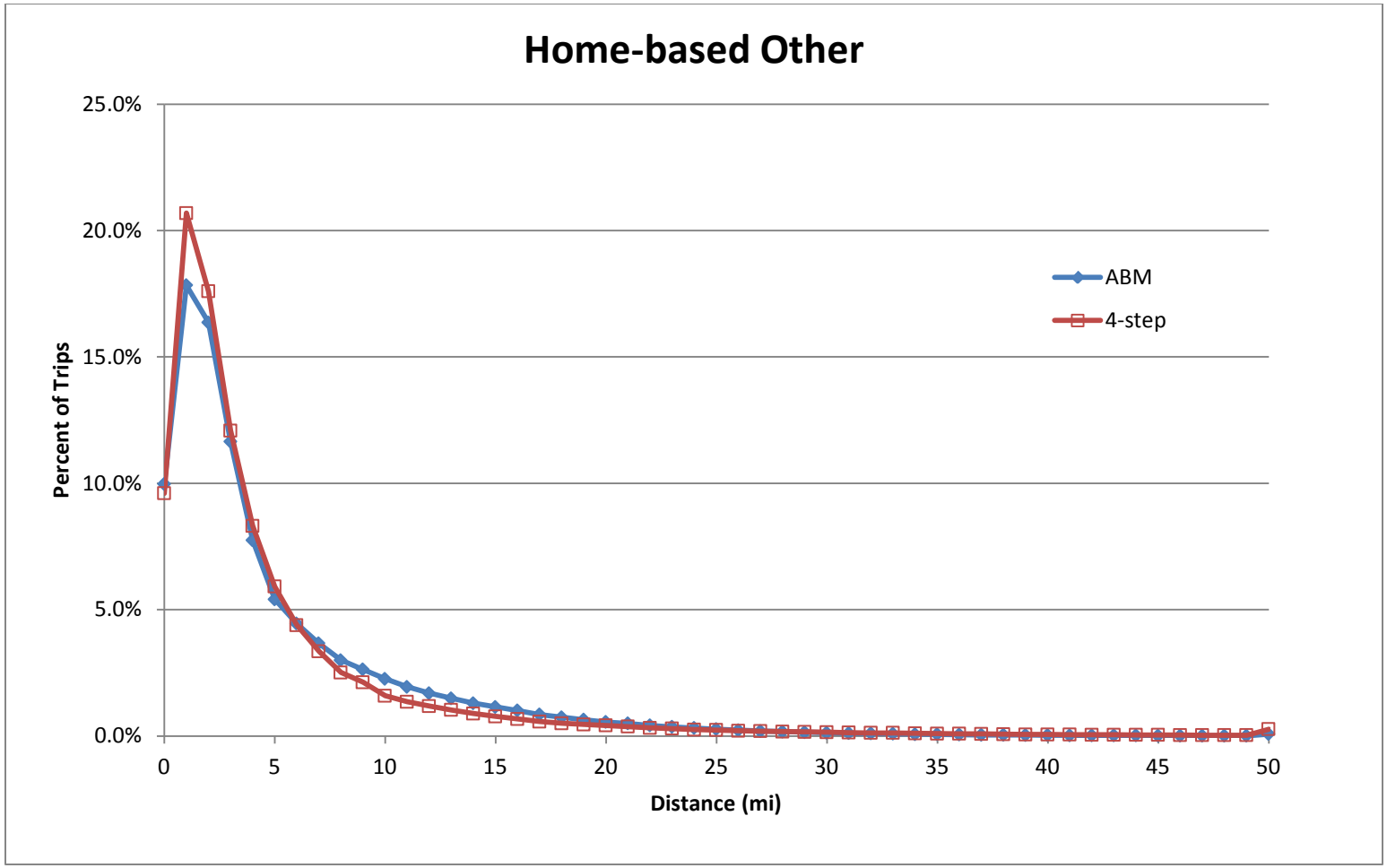

Figure 7: Home-Based Other Trip Length Frequency Distribution

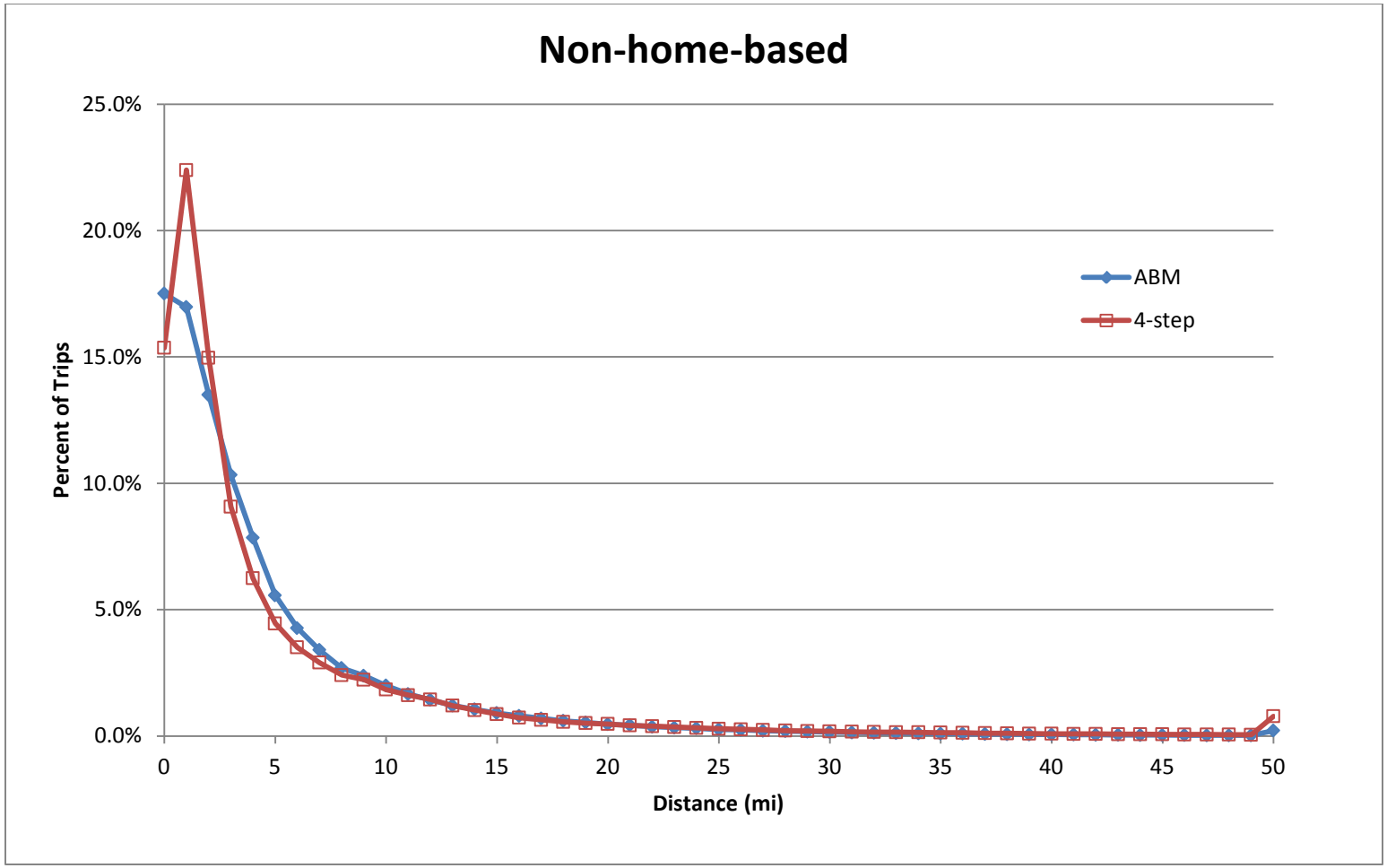

Figure 8: Non-Home-Based Trip Length Frequency Distribution

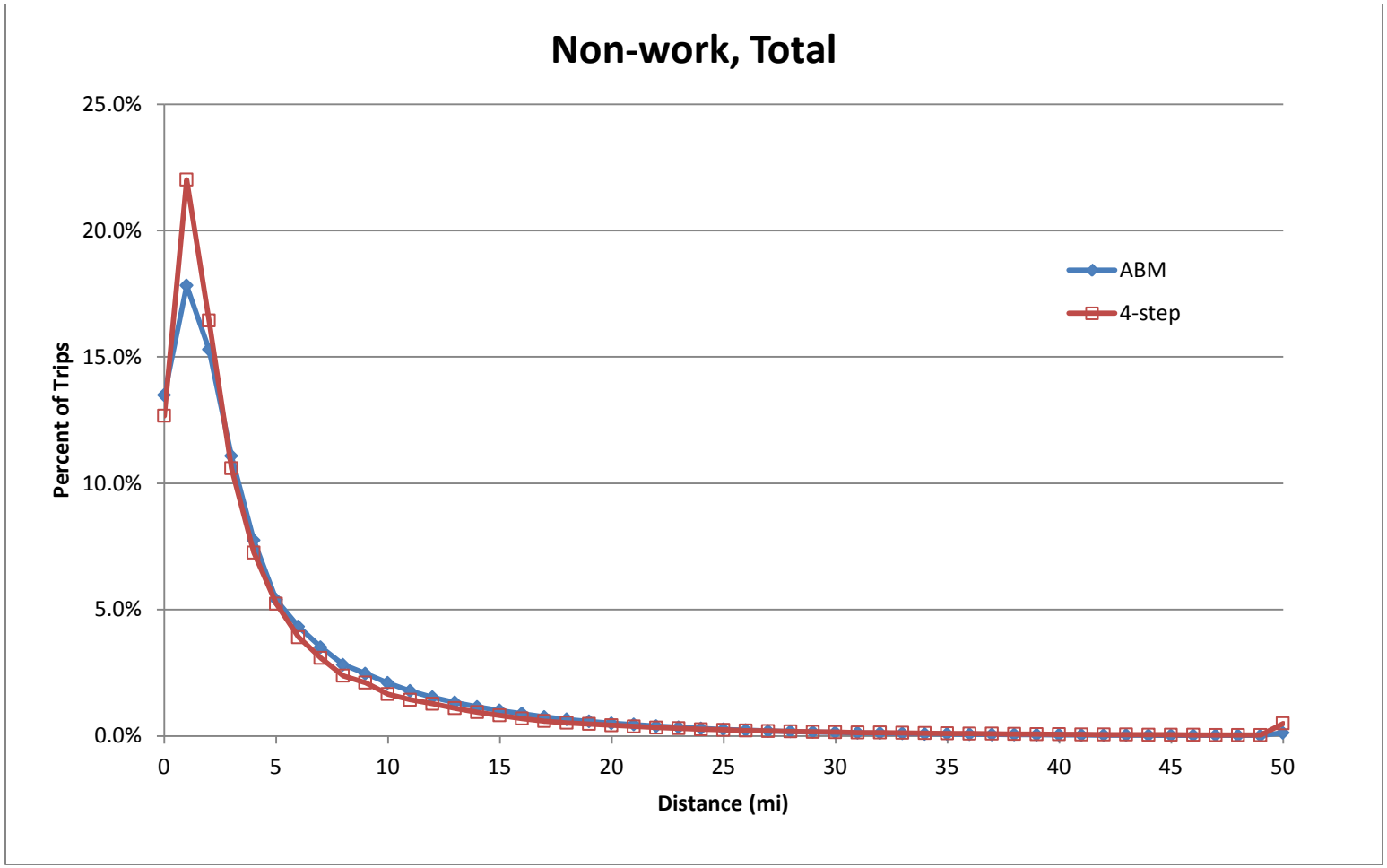

Figure 9: Non-Work Trip Length Frequency Distribution, Total

5 Mode Choice

This section presents the results for the number of trips by mode of travel.

The trip-based model determines the number of trips by mode between each production and attraction zone by applying aggregate shares to the total number of trips. The aggregate shares are calculated using a nested logit model. The mode choice models are segmented by purpose and include constants specific to each combination of automobile ownership level and household income category. Further, geographic-specific constants specific to production super-district by income quartile were introduced to match the observed mode split for the home-based work purpose.

The activity-based model also uses nested logit models segmented by purpose, but the utility functions are specific to the individual, and the chosen modes are simulated for each person separately. After tours are scheduled, a tour mode is selected. This tour mode determines what particular modes will be considered for each trip. The modes of individual trips are then chosen based on the tour mode and the attributes of the available modes. For example, drive alone is not available as a trip mode on a walk-to-transit tour. The models have separate constants specific to automobile ownership categories, but not geographic areas.

Table 11 shows the modal distribution of home-based work trips by income quartile for the trip-based model, activity-based model, and CTPP. Note that the activity based model contains fewer home-based work trips than the other sources for reasons noted earlier.

Overall, the distributions for the three sources are similar. The activity-based model contains a higher share of transit and non-motorized trips because its calibration was designed to match the household survey and transit on-board survey results. These sources should be more accurate than the Census, which asks only for the "usual" mode to work; non-auto trips made by workers who usually drive to work but occasionally use other modes are suppressed in the Census.

Table 12 shows the modal distribution of other trips for the trip-based and activity-based models. The trip-based model validation document did not contain observed data for comparison. Again, the activity-based model contains different numbers of trips by purpose (see section 3 *Trip Generation*). The mode choice results from the trip- and activity-based models are comparable.

Table 11: Travel Mode of Home-Based Work Trips by Household Income

Trip Purpose	Trips			Share		
Travel Mode	Census	4-step	ABM	Census	4-step	ABM
HBW, Income Quartile 1						
Drive Alone	354,024	347,281	248,050	60.0%	59.4%	59.6%
Shared Ride 2	60,212	62,169	29,871	10.2%	10.6%	7.2%
Shared Ride 3+	21,971	23,279	13,441	3.7%	4.0%	3.2%
Transit	88,209	87,732	77,327	15.0%	15.0%	18.6%
Bicycle	12,520	12,413	12,159	2.1%	2.1%	2.9%
Walk	52,966	52,015	35,154	9.0%	8.9%	8.5%
Total	589,907	584,889	416,002	100.0%	100.0%	100.0%
HBW, Income Quartile 2						
Drive Alone	694,267	690,233	572,994	68.7%	68.0%	64.6%
Shared Ride 2	107,921	109,290	68,840	10.7%	10.8%	7.8%
Shared Ride 3+	38,728	41,060	29,931	3.8%	4.0%	3.4%
Transit	116,295	120,932	140,762	11.5%	11.9%	15.9%
Bicycle	12,934	13,203	21,035	1.3%	1.3%	2.4%
Walk	39,906	40,067	53,364	4.0%	3.9%	6.0%
Total	1,010,039	1,014,785	886,926	100.0%	100.0%	100.0%
HBW, Income Quartile 3						
Drive Alone	1,158,932	1,151,119	873,405	73.1%	72.2%	66.6%
Shared Ride 2	162,171	164,390	120,286	10.2%	10.3%	9.2%
Shared Ride 3+	55,122	57,484	54,644	3.5%	3.6%	4.2%
Transit	152,859	165,788	198,454	9.6%	10.4%	15.1%
Bicycle	15,586	16,116	21,958	1.0%	1.0%	1.7%
Walk	39,863	40,037	42,628	2.5%	2.5%	3.3%
Total	1,584,534	1,594,934	1,311,375	100.0%	100.0%	100.0%
HBW, Income Quartile 4						
Drive Alone	1,537,221	1,537,691	1,153,648	75.8%	74.9%	66.9%
Shared Ride 2	194,787	196,154	166,108	9.6%	9.6%	9.6%
Shared Ride 3+	61,466	63,669	72,332	3.0%	3.1%	4.2%
Transit	175,929	197,704	255,423	8.7%	9.6%	14.8%
Bicycle	17,831	18,579	27,028	0.9%	0.9%	1.6%
Walk	40,030	39,876	49,314	2.0%	1.9%	2.9%
Total	2,027,259	2,052,642	1,723,853	100.0%	100.0%	100.0%
HBW, Total						
Drive Alone	3,744,444	3,726,324	2,848,097	71.8%	71.0%	65.7%
Shared Ride 2	525,091	532,003	385,106	10.1%	10.1%	8.9%
Shared Ride 3+	177,287	185,492	170,346	3.4%	3.5%	3.9%
Transit	533,292	572,156	671,966	10.2%	10.9%	15.5%
Bicycle	58,871	60,311	82,178	1.1%	1.1%	1.9%
Walk	172,765	171,995	180,461	3.3%	3.3%	4.2%
Total	5,211,739	5,248,281	4,338,154	100.0%	100.0%	100.0%

Table 12: Travel Mode of Other Trips by Purpose

Trip Purpose	Trips		Share	
Travel Mode	4-step	ABM	4-step	ABM
Home-Based School				
Auto	1,608,253	1,362,813	70.1%	67.4%
Transit	172,876	247,069	7.5%	12.2%
Bicycle	99,124	31,715	4.3%	1.6%
Walk	414,346	379,412	18.1%	18.8%
Total	2,294,599	2,021,009	100.0%	100.0%
Home-Based Other				
Drive Alone	3,284,593	4,701,503	42.8%	47.5%
Shared Ride 2	2,013,838	2,188,537	26.3%	22.1%
Shared Ride 3+	1,341,068	1,713,075	17.5%	17.3%
Transit	277,669	271,650	3.6%	2.7%
Bicycle	102,308	109,081	1.3%	1.1%
Walk	650,806	921,301	8.5%	9.3%
Total	7,670,282	9,905,147	100.0%	100.0%
Non-Home-Based				
Auto	4,905,688	5,457,026	84.3%	85.0%
Transit	152,854	71,792	2.6%	1.1%
Bicycle	48,846	34,846	0.8%	0.5%
Walk	713,275	857,446	12.3%	13.4%
Total	5,820,663	6,421,110	100.0%	100.0%
Non-Work, Total				
Auto	13,153,440	15,422,954	83.3%	84.1%
Transit	603,399	590,511	3.8%	3.2%
Bicycle	250,278	175,642	1.6%	1.0%
Walk	1,778,427	2,158,159	11.3%	11.8%
Total	15,785,544	18,347,266	100.0%	100.0%

6 Highway Assignment

This section presents results for the number of vehicles passing selected locations on the highway network. The same general method is used by the trip- and activity-based models to assign vehicle trips to the highway network: both models iteratively find a solution to the static user equilibrium condition that no traveler may be able to save time by unilaterally switching routes (certain parameters, such as the value of time and the generalized cost function differ). Differences between the two models emerge primarily from differences in vehicle trip tables.

In addition to using k-factors in trip distribution and geographic-specific constants in mode choice, the trip-based model applied static factors to increase or decrease the number of trips between certain counties after mode choice in order to match observed volumes on the Bay Area bridges. The activity-based model does not use any such factoring.

Daily traffic volumes for the trip- and activity-based models are compared to averaged automatic vehicle counts from the Caltrans highway performance monitoring database in Table 13. The data sources are in overall agreement, although because of the avoidance of trip table factoring, the activity-based model does have slightly too much traffic on the lower-volume bridges, and too much traffic crossing between Santa Clara and Alameda counties. Time-of-day-specific validation of traffic is available in the activity-based model calibration and validation report.

Table 13: Daily Traffic Estimates at Key Locations

Screenline	Avg. Daily Traffic			Difference		Pct. Difference	
Facility	Caltrans	4-step	ABM	4-step	ABM	4-step	ABM
Bay Area Bridges							
US-101, Golden Gate Bridge	119,274	126,338	106,635	7,064	-12,639	5.9%	-10.6%
I-80, SF/Oakland Bay Bridge	283,903	270,668	298,043	-13,235	14,140	-4.7%	5.0%
Cal-92, San Mateo/Hayward Bridge	88,568	91,908	108,249	3,340	19,681	3.8%	22.2%
Cal-84, Dumbarton Bridge	81,933	79,149	105,327	-2,784	23,394	-3.4%	28.6%
I-580, Richmond/San Rafael Bridge	75,829	73,922	100,884	-1,907	25,055	-2.5%	33.0%
I-80, Carquinez Bridge	112,540	114,183	120,802	1,643	8,262	1.5%	7.3%
I-680, Benicia/Martinez Bridge	106,272	120,576	135,032	14,304	28,760	13.5%	27.1%
Cal-160, Antioch Bridge	12,506	12,545	12,638	39	132	0.3%	1.1%
Bay Area Bridges Sub-Total	***880,825***	***889,289***	***987,610***	***8,464***	***106,785***	**1.0%**	**12.1%**
San Francisco/San Mateo Line							
US-101, Bayshore Freeway	216,727	193,837	192,819	-22,890	-23,908	-10.6%	-11.0%
Cal-35, Skyline Blvd.	25,535	12,363	10,089	-13,172	-15,446	-51.6%	-60.5%
Cal-1, Junipero Serra Blvd.	110,423	106,334	115,800	-4,089	5,377	-3.7%	4.9%
I-280, Foran Freeway	140,622	116,193	95,513	-24,429	-45,109	-17.4%	-32.1%
SF/SM County Line Sub-Total	***493,307***	***428,727***	***414,221***	***-64,580***	***-79,086***	**-13.1%**	**-16.0%**
San Mateo/Santa Clara Line							
Cal-82, El Camino Real	39,589	47,741	24,382	8,152	-15,207	20.6%	-38.4%

Screenline	Avg. Daily Traffic			Difference		Pct. Difference	
Facility	Caltrans	4-step	ABM	4-step	ABM	4-step	ABM
US-101, Bayshore Freeway	224,856	236,380	239,481	11,524	14,625	5.1%	6.5%
I-280, Serra Freeway	121,586	122,189	112,002	603	-9,584	0.5%	-7.9%
SM/SC County Line Sub-Total	***386,031***	***406,310***	***375,865***	***20,279***	***-10,166***	**5.3%**	**-2.6%**
Santa Clara/Alameda Line							
I-680, at Scott Creek Road	167,884	131,100	155,608	-36,784	-12,276	-21.9%	-7.3%
I-880, Nimitz Freeway	166,539	205,526	220,146	38,987	53,607	23.4%	32.2%
SC/Ala County Line Sub-Total	***334,423***	***336,626***	***375,754***	***2,203***	***41,331***	**0.7%**	**12.4%**
Alameda/Contra Costa Line							
I-580, Knox Freeway	83,663	110,697	124,008	27,034	40,345	32.3%	48.2%
I-80, Eastshore Freeway	175,781	170,331	199,496	-5,450	23,715	-3.1%	13.5%
Cal-24, Caldecott Tunnel	172,724	173,118	198,720	394	25,996	0.2%	15.1%
I-680, in Dublin/San Ramon	136,320	145,065	185,265	8,745	48,945	6.4%	35.9%
Ala/CC County Line Sub-Total	***568,488***	***599,211***	***707,489***	***30,723***	***139,001***	**5.4%**	**24.5%**
Solano/Napa County Line							
Route 29, Napa-Vallejo Highway	32,360	41,300	31,447	8,940	-913	27.6%	-2.8%
Solano/Sonoma County Line							
Route 37, Sears Point Road	41,014	34,330	21,526	-6,684	-19,488	-16.3%	-47.5%
Napa/Sonoma County Line							
Route 121, Carneros Highway	31,166	24,061	16,690	-7,105	-14,476	-22.8%	-46.4%
Route 128, Calistoga-Healdsburd	1,813	2,329	1,728	516	-85	28.5%	-4.7%
Napa/Sonoma Line Sub-Total	***32,979***	***26,390***	***18,418***	***-6,589***	***-14,561***	**-20.0%**	**-44.2%**
Sonoma/Marin County Line							
US-101, Redwood Highway	71,125	87,553	65,985	16,428	-5,140	23.1%	-7.2%
Screenline Totals	***2,840,552***	***2,849,736***	***2,998,315***	***9,184***	***157,763***	**0.3%**	**5.6%**

7 Transit Assignment

This section presents results for the number of persons boarding transit vehicles at selected locations on the transit network. The same general method is used by the trip- and activity-based models to assign person trips to the transit network: both models assign all trips on a given mode to the single best path between each origin and destination. The differences between the two approaches are substantial and include: the activity-based model builds ten separate path options for each of five time periods for each origin/destination pair; the trip-based model builds one or two (depending on the trip purpose) separate path options for one or two (depending on the trip purpose) time periods for each production/attraction pair. Even with these differences, the primary difference in the outcomes is likely due to differences between the trip tables driving the assignment.

Table 14 shows the number of transit vehicle boardings for each operator in the trip-based model, activity-based model, and observed data. In addition to using k-factors in trip distribution, the trip-based mode choice model contains alternative-and-geographic-specific constants for each super-district pair in the region. This approach dramatically improves the trip-based model's ability to match the number of boardings by operator in the base year. However, this type of calibration can leave the model insensitive to changes in demographics, congestion, or transit level of service (i.e. the size of the constants may dwarf the potential change in the other variables included in the utility expressions).

The activity-based model does an acceptable job of matching transit boardings by operator without using heavy-handed calibration techniques. The large deficit of boardings on certain systems, such as the cable car system, are expected. The developers have chosen not to match specific operator ridership in certain cases until a realistic behavioral interpretation, such as a visitor model in the case of cable cars, can be built into the activity-based model as it is refined.

Table 15 shows the number of transit vehicle boardings for each aggregate mode, with individual operators collected together. This table indicates that the magnitude of the deviations for each aggregate mode tend to be smaller in the activity-based model. In both the trip- and activity-based models, the total number of transit boardings is within 1 percent of the observed total.

Table 16 shows the number of daily entries and exits on the BART system in both models, compared to observed fare gate data. The overall pattern of deviations is consistent between the trip- and activity-based models, but the magnitude of geographic discrepancies in the trip-based model is somewhat smaller (again, the use geographic-specific constants helps fit the model in this respect). The only large deviation apparent in the activity-based model results is the excess of 27,000 trip ends with entries and exits in Downtown Oakland, between the MacArthur and West Oakland stations.

Table 14: Transit Vehicle Boardings by Operator

Operator	Mode	Number of Boardings			Difference		Percent Difference	
		Observed	4-step	ABM	4-step	ABM	4-step	ABM
MUNI Bus	Bus	562,970	606,016	467,173	43,046	-95,797	7.6%	-17.0%
AC Local	Bus	186,983	196,868	244,979	9,885	57,996	5.3%	31.0%
VTA Local	Bus	149,868	163,470	190,877	13,602	41,009	9.1%	27.4%
Samtrans Local/Exp	Bus	62,557	63,476	91,790	919	29,233	1.5%	46.7%
Golden Gate Local/Exp	Bus	33,383	34,307	27,327	924	-6,056	2.8%	-18.1%
MUNI Cable Car	Bus	22,813	19,733	12,893	-3,080	-9,920	-13.5%	-43.5%
CCCTA Local	Bus	15,486	16,824	24,833	1,338	9,347	8.6%	60.4%
AC Transbay	Bus	13,917	13,889	15,694	-28	1,777	-0.2%	12.8%
Sonoma Providers	Bus	10,772	10,091	15,766	-681	4,994	-6.3%	46.4%
Other Shuttles	Bus	9,000	13,642	14,904	4,642	5,904	51.6%	65.6%
Tri-Delta	Bus	7,580	7,049	11,770	-531	4,190	-7.0%	55.3%
LAVTA/Wheels	Bus	6,003	6,111	10,044	108	4,041	1.8%	67.3%
Vallejo Local	Bus	4,481	8,556	6,455	4,075	1,974	90.9%	44.1%
West Cat Express	Bus	3,101	5,098	2,230	1,997	-871	64.4%	-28.1%
Fairfield Local	Bus	3,037	2,978	4,899	-59	1,862	-1.9%	61.3%
Stanford Shuttle	Bus	2,918	5,262	7,242	2,344	4,324	80.3%	148.2%
Emery Shuttle	Bus	2,860	2,795	4,319	-65	1,459	-2.3%	51.0%
NVT/Vine	Bus	2,427	2,598	33	171	-2,394	7.0%	-98.6%
Union City	Bus	1,920	2,252	3,706	332	1,786	17.3%	93.0%
BWS	Bus	971	558	26	-413	-945	-42.5%	-97.3%
DBX	Bus	867	1,525	2,245	658	1,378	75.9%	158.9%
Air BART	Bus	750	722	70	-28	-680	-3.7%	-90.7%
Vacaville	Bus	543	797	137	254	-406	46.8%	-74.8%
American Canyon	Bus	500	193	2	-307	-498	-61.4%	-99.6%
MUNI Metro	Light Rail	168,510	135,289	126,211	-33,221	-42,299	-19.7%	-25.1%
VTA LRT	Light Rail	30,144	27,250	48,728	-2,894	18,584	-9.6%	61.7%
Golden Gate Ferry	Ferry	6,179	6,180	8,130	1	1,951	0.0%	31.6%
East Bay Ferries	Ferry	2,546	2,422	4,145	-124	1,599	-4.9%	62.8%
Vallejo Ferries	Ferry	2,137	2,384	151	247	-1,986	11.6%	-92.9%
Tiburon Ferries	Ferry	1,307	1,062	240	-245	-1,067	-18.7%	-81.6%
BART	Heavy Rail	344,869	324,048	332,759	-20,821	-12,110	-6.0%	-3.5%
Caltrain	Commuter Rail	31,291	27,273	33,527	-4,018	2,236	-12.8%	7.1%
ACE	Commuter Rail	1,743	1,431	42	-312	-1,701	-17.9%	-97.6%
Amtrak	Commuter Rail	1,015	955	88	-60	-927	-5.9%	-91.3%
Total		1,695,448	1,713,104	1,713,435	17,656	17,987	1.0%	1.1%

Table 15: Transit Vehicle Boardings by Mode

Mode	Number of Boardings			Difference		Percent Difference	
	Observed	4-step	ABM	4-step	ABM	4-step	ABM
Bus	1,105,707	1,184,810	1,159,414	79,103	53,707	7.2%	4.9%
Light Rail	198,654	162,539	174,939	-36,115	-23,715	-18.2%	-11.9%
Ferry	12,169	12,048	12,666	-121	497	-1.0%	4.1%
Heavy Rail	344,869	324,048	332,759	-20,821	-12,110	-6.0%	-3.5%
Commuter Rail	34,049	29,659	33,657	-4,390	-392	-12.9%	-1.2%
Total	1,695,448	1,713,104	1,713,435	17,656	17,987	1.0%	1.1%

Table 16: BART Entries and Exits by Station

Station	Entries + Exits			Difference		Percent Difference	
	Observed	4-step	ABM	4-step	ABM	4-step	ABM
Bayfair	10,542	14,119	12,856	3,577	2,314	33.9%	22.0%
San Leandro	10,339	11,611	14,703	1,272	4,364	12.3%	42.2%
Coliseum / Oakland Airport	13,795	8,356	9,735	-5,439	-4,060	-39.4%	-29.4%
Fruitvale	16,990	19,133	18,671	2,143	1,681	12.6%	9.9%
Lake Merritt	9,163	10,184	16,050	1,021	6,887	11.1%	75.2%
Fremont to Lake Merritt Sub-Total	**97,550**	**90,292**	**72,015**	**-7,258**	**-25,535**	**-7.4%**	**-26.2%**
MacArthur	12,960	17,293	27,092	4,334	14,132	33.4%	109.0%
19th Street Oakland	16,647	22,267	26,272	5,620	9,625	33.8%	57.8%
12th Street / Oakland City Center	24,829	20,486	30,580	-4,343	5,751	-17.5%	23.2%
West Oakland	9,952	6,925	7,656	-3,027	-2,296	-30.4%	-23.1%
Mac Arthur to West Oakland Sub-Total	**64,388**	**66,972**	**91,600**	**2,584**	**27,212**	**4.0%**	**42.3%**
Concord	12,259	7,506	16,860	-4,753	4,601	-38.8%	37.5%
Pleasant Hill	13,760	8,951	6,503	-4,810	-7,257	-35.0%	-52.7%
Walnut Creek	12,069	12,932	14,716	863	2,647	7.1%	21.9%
Lafayette	6,165	5,710	5,291	-454	-874	-7.4%	-14.2%
Orinda	5,304	5,472	3,791	168	-1,513	3.2%	-28.5%
Rockridge	9,460	9,902	10,969	442	1,509	4.7%	16.0%
North Concord	4,058	1,144	885	-2,914	-3,173	-71.8%	-78.2%
Pittsburg/Bay Point	9,557	11,970	11,449	2,413	1,892	25.3%	19.8%
Pittsburg to Rockridge Sub-Total	**72,631**	**63,586**	**70,464**	**-9,045**	**-2,167**	**-12.5%**	**-3.0%**
Richmond	8,175	10,175	23,185	2,000	15,010	24.5%	183.6%
El Cerrito Del Norte	16,918	17,432	6,126	514	-10,792	3.0%	-63.8%
El Cerrito Plaza	8,001	10,635	7,147	2,634	-854	32.9%	-10.7%
North Berkeley	21,435	15,402	21,014	-6,033	-421	-28.1%	-2.0%
Berkeley	7,508	8,965	8,477	1,457	969	19.4%	12.9%
Ashby	8,731	6,700	8,884	-2,032	153	-23.3%	1.8%
Richmond to Ashby Sub-Total	**70,769**	**69,309**	**74,833**	**-1,459**	**4,064**	**-2.1%**	**5.7%**
Embarcadero	68,678	85,196	70,203	16,517	1,525	24.0%	2.2%
Montgomery Street	71,768	86,067	58,705	14,299	-13,063	19.9%	-18.2%
Powell Street	53,135	31,703	25,329	-21,432	-27,806	-40.3%	-52.3%
Civic Center	36,232	27,009	27,230	-9,223	-9,002	-25.5%	-24.8%
16th Street Mission	18,682	18,004	22,222	-678	3,540	-3.6%	18.9%
24th Street Mission	23,494	23,825	22,348	332	-1,146	1.4%	-4.9%
Glen Park	14,958	6,026	17,919	-8,932	2,961	-59.7%	19.8%
Balboa Park	23,948	13,795	7,010	-10,153	-16,938	-42.4%	-70.7%
Daly City	16,031	23,474	24,654	7,443	8,623	46.4%	53.8%
Colma	13,946	19,180	25,731	5,234	11,785	37.5%	84.5%
Embarcadero to Colma Sub-Total	**340,871**	**334,279**	**301,351**	**-6,593**	**-39,520**	**-1.9%**	**-11.6%**
Castro Valley	4,273	3,321	5,443	-952	1,170	-22.3%	27.4%
Dublin/Pleasanton	12,599	12,283	8,265	-316	-4,334	-2.5%	-34.4%
Dublin to Castro Valley Sub-Total	**16,872**	**15,604**	**13,708**	**-1,268**	**-3,164**	**-7.5%**	**-18.8%**
Total Entries+Exits	***663,081***	***640,042***	***623,971***	***-23,040***	***-39,110***	***-3.5%***	***-5.9%***

8 Conclusion

The aggregate results for the legacy trip-based model and the new activity-based model are highly consistent. The activity-based model includes fewer home-based work trips, but this difference is counter-balanced by more home-based other trips and non-home-based trips. These differences appear to be due to the ability of the activity-based model to more accurately represent intermediate stops on tours, and to differences between the Census and household survey calibration targets. The slightly greater number of non-work trips in the activity-based model allowed for the reduction of the excessive number of small truck trips included in the trip-based model.

The distribution and lengths of trips match closely between the two models, and the activity-based model matches the distribution of residence-work exchanges from the Census nearly as closely as the trip-based model; this match is achieved in the activity-based model without k-factors. The aggregate shares of trips by mode is similar, but the activity-based model estimates more non-auto trips.

The loaded highway and transit networks have similar traffic volumes and transit vehicle boardings, and both match observed data closely. While the trip-based model more closely matches the observed data on a small scale, it has been fit with a heavy hand via direct trip table adjustments and geographic-specific mode choice constants. The approach taken in the activity-based model development should provide more accurate sensitivity to changes in model inputs that may be introduced in future scenarios. This improved sensitivity should result in more accurate forecasts.